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Department of Civil Engineering
Masters of Engineering specialising in Transport Studies

Unpacking Road Safety at a District Level- The Case of Cape Town, South Africa

60-credit Minor Dissertation (CIV 5017Z)

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Plagiarism Declaration

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This work is dedicated to my mother, FJ and my sister, SN.

Thank you for your love, strength and belief in me.

Abstract

In South Africa, the legacy of apartheid planning established vast differences within cities in terms of household income, consequently, the population in different areas are exposed to varying road environments. These road environments include, for instance, the mode usage of the population that exposes them to varying traffic conditions. The literature suggests that there is a need to understand road fatalities further, so as to articulate informed interventions by determining the impact of these environments on road fatalities, at a more disaggregated level than that of cities. With road fatality levels remaining high within the country, this study aims to perform this disaggregated study for Cape Town.

In this study, Cape Town fatality data for the 2011-2015 period was analysed on a 2013 Traffic Analysis Zone level, defined in this study as the analysis district. The analysis included determining absolute fatalities and fatality rates, comparing mode usage with fatalities, and imputing the mode involved in fatalities. Geocoded data was also used to extract the top 10 hazardous zones in the city by ranking them based on the number of road fatalities and describing the fatality conditions in the top three zones.

Analysis revealed that pedestrians constitute the majority of road fatalities in the city (58%) and all analysis districts. Furthermore, the low-income districts had a high road fatality burden per annum, but a low fatality rate that was comparable to high-income countries. Alternatively, high-income districts had a low road fatality burden per annum, but a high fatality rate. It was also found that percentage fatalities that impact pedestrians and cyclists are more than the percentage of the population that walk and cycle in the city. In terms of modes involved in fatalities, the Forensic Pathology Services data contained a large percentage of missing data (54%) hence, the analysis showed inconclusive results. Lastly, geocoded data revealed that the top three hazardous zones in the city – N1 and N7 junction, Table Bay Boulevard (N1) and M30 and R101 junction – continue to impact pedestrians crossing high-speed arterials. The dataset also suggested that risky driver behaviour and lighting is a major problem in these zones.

From the results, it can be inferred that the prescribed interventions need to target pedestrian fatalities at both an aggregated and a disaggregated level. In the case of the hazardous zones, these localised interventions need to include reducing speed limits along residential roads, providing adequate lighting and creating safe pedestrian crossing facilities along desire lines. Moreover, both, average annual fatalities and fatality rates, need to be determined when prioritising areas for road safety measures. Lastly, given the percentage of missing data, the fatality burden in the city is underrepresented, which suggests there is a need to improve data capturing in the field. While this study has been adopted towards the Cape Town context, the principles of this study can be implemented in countries with high fatality burdens, which mainly include low- and middle-income countries.

Summary

Motivation

In developing countries, road fatality rates are more than double the fatality rates of High-Income Countries (HIC) (World Health Organisation (WHO), 2015). This imbalance is astounding when considering the fact that Low- and Middle-Income Country (LMIC) account for 82% of the world population but only account for 54% of the world's registered vehicles. Naci *et al.* (2009) found that there is also a variation in terms of the road users affected in these countries, with pedestrians constituting the majority of fatalities in LMIC, and private car users constituting the majority of the fatalities in HIC. Since HIC have managed to reduce road traffic deaths successfully over the years, governments in LMIC have, generally, adopted interventions from HIC without understanding the local context. However, with road traffic deaths being at a plateau since 2007, there is a need to understand fatal road crashes at a more disaggregated level in order to reduce road fatalities successfully.

The situation in African countries is similar to other LMIC, with vulnerable road users, i.e. pedestrians, motorcyclists and cyclists, constituting the bulk (52%) of road fatalities (WHO, 2015). However, the vulnerability of road users depends on the country considered (Peden *et al.*, 2013) and whether the area considered within a country is rural or urban (Nantulya and Reich, 2003). In terms of African countries, the fatalities rates in Nigeria and South Africa are the highest at 33.7 and 31.9 per 100 000 population (Peden *et al.*, 2013), respectively. In terms of the area considered, Odero (1997, cited by Odero *et al.*, 2003) confirmed that in rural areas of Kenya, majority of fatalities affected public transport passengers while in urban areas of Kenya, majority of road victims are pedestrians.

In South Africa, apartheid planning has led to vast variations within cities in terms of income and mode usage of households. For instance, in this study, the 2013 National Household Travel Survey (NHTS) data for Cape Town was analysed, and the data concurred that in townships, majority of the population used walking as their main mode of transport. The opposite was true for land designated for the white minority during apartheid, with households relying heavily on private car use. As a result, the road environments for households in these two areas, are significantly different. Therefore, there is a need to unpack road safety at a more disaggregated level than the city as a whole in order to determine the impact of the local environments on road safety. These local environments include, for instance, the mode usage of the population at that level which exposes them to varying traffic conditions. In this study, the focus is oriented towards determining the burden of road fatalities in Cape Town at a 2013 NHTS TAZ level, which is defined as an analysis district.

Background

This study originated from a Western Cape Province funded project, *Road Safety Implementation Programme for the Province,* which appointed academics from the Universities of Cape Town and Stellenbosch to perform this task. Two sources of fatality data – the Forensic Pathology Services (FPS) and the Provincial Accident System (iPAS) – were used to analyse the road safety burden in Western Cape Traffic Analysis Zones (TAZs) as defined by the 2013 NHTS. The projected data included a separate analysis for Cape Town because of its metropolitan status in the province, and because a little over half of the fatalities observed in the Western Cape transpired in the city. As mentioned previously, this particular analysis will be elaborated upon further, in order to present the road safety status quo of Cape Town analysis districts.

Methodology adopted

The literature reviewed determined the current road safety situation at a world, African and at a national level. At world level, the literature on the road safety status quo of LMIC and HIC was reviewed. Specific research also extracted best practices from LMIC and HIC that successfully reduced the road fatalities in these countries. As mentioned previously, the literature stated that local environments, such as mode usage of the population at a disaggregated level, had an effect on road fatalities at that level. Consequently, three databases were identified to perform the analysis at this level – NHTS (2013), FPS (2011-2015) and iPAS (2011-2015). These datasets provided information on population, mode usage, absolute fatalities and geocoded fatality locations to perform a comprehensive road safety analysis in Cape Town.

Data from the NHTS (2013), provided population and mode usage information for each analysis district in Cape Town. The absolute fatalities from FPS (2011-2015) were then analysed to determine the total fatalities and fatalities per annum for five road users – drivers, cyclists, motorcyclists, pedestrians and passengers, over five years. Following this, mathematical calculations using the data, determined fatality rates/ 100 000 population and the difference between fatalities and mode usage. The fatality rate is an international measure that denotes the risk of dying, due to a road traffic crash (WHO, 2015), while the difference between fatalities and mode usage signifies whether the number of road deaths, for a particular road user group in a district, are more than the relative percentage of the population that uses of the mode.

The FPS data also provided information on the mode involved in the fatalities. The vehicle data analysis provided the risk per registered vehicle, similar to analysis performed by Jungu-Omara and Vanderschuren (2006). The final part of the analysis utilised geocoded data to determine the hazardous zones of the city by ranking the zones in terms of the fatality numbers (Elvik, 2007). Since iPAS data provides better information than FPS data in terms of fatality conditions, both datasets were used in tandem for this analysis. Lastly, the analysis findings were presented on info-maps created in ArcGIS and MS Excel charts for ease of interpretation.

Results of the study

The analysis determined that the road safety burden in Cape Town is high with 3 334 fatalities occurring over the five years analysed (51% of Western Cape fatalities during the same period). In terms of road users affected, pedestrians constituted the majority of fatalities (58%), followed by drivers (17%) and passengers (16%). Literature from RTMC (2015) suggested that this order is partially different in South Africa, with pedestrians constituting of majority of road fatalities (37.6%) followed by passengers (32%) and drivers (27%). Pedestrians remained to be the most affected in each district, however drivers and passengers were either the second or the third most affected road user, depending on the district considered.

In low-income areas, average annual fatality rates were high with fatality rates per 100 000 population found to be low and in some cases, comparable to high-income countries. For instance, Mitchells Plain had an average of 62 fatalities per year but a fatality rate of 11.9 per 100 000 population, which is less than both the World average of 17.4 (WHO, 2015) and African average of 24.1 (Peden *et al.*, 2013). Alternatively, in high-income areas, the opposite was found to be true with average fatalities per year being low but fatality rates per 100 000 population being high. For instance, in Somerset West, an average of 10 fatalities per year were recorded, whereas the equivalent fatality rate was 28.9 per 100 000 population, which is more than the World and African average.

The analysis of percentage differences of fatalities and mode usage found that, in the City, the percentage fatalities that affect pedestrians and cyclists were more than the percentage of population that travel by walking and cycling (see Figure 4-6). In the case of drivers and passengers, the opposite was found to be true (also see Figure 4-6). However, when considering the analysis districts specifically, the analysis showed conflicting results for drivers and cyclists. In high-income areas, the percentage of driver fatalities were less than the percentage of the population that drove while in low-income areas, the percentage of cyclist fatalities were less than the percentage of the population that cycled.

FPS data on ‘mode involved in road fatalities’ contained only 46% of usable data with 54% of data records designated ‘blank’, ‘unknown’ or other (see Figure 4-13). As a result, sufficient data was not available to represent the actual risk per vehicle type. However, the literature from Jungu-Omara and Vanderschuren (2006) inferred that sedans are involved in majority of the fatalities (66%) in Cape Town but in terms of accident risk, MBTs pose the greatest threat to road users (0.88).

Lastly, the geocoded data identified the top 10 hazardous zones in the city with a detailed description on fatality conditions provided for the top three zones due to the limitation of this study. The findings from the FPS data showed a large set of anomalies, similar to the vehicle data, therefore, analysis was limited to the top three zones identified by the iPAS dataset – N1 and N7 junction, Table Bay Boulevard (N1) and M30 and R101 junction. Fatal crashes in these zones varied from 33 to 9 with 37 to 10 fatalities occurring from 2011 to 2015. The fatalities in two of the three sites – N1 and N7 junction and M30 and R101 junction – constituted of mostly pedestrians with pedestrians crossing high speed roads presumed to be the main cause in these areas based on previous findings by Behrens (2002). The dataset suggested that risky or unsafe driver behaviour caused majority of the fatal crashes. For each zones, the literature on best practices provided interventions that may have a positive impact. These interventions include, introducing pedestrian bridges along pedestrian desire lines (Slingers, 2012), reducing speed limits on roads that run through residential areas (Waiz *et al.*, 1983) and improving roadway visibility by providing adequate lighting (Vanderschuren *et al*., 2017).

Conclusions and Recommendations

The findings suggest that firstly, the road fatality burden in Cape Town is high with almost 670 fatalities/year occurring in the five years analysed. Secondly, the burden of road fatalities is not equal for all road users, with pedestrians being the most affected road user in the City followed by drivers and passengers, respectively. In terms of the analysis districts, the order changed for drivers and passengers, which suggests that road safety analysis at a disaggregated level, is important when determining the road user that should be targeted for interventions. This is especially true for LMIC where road safety budgets are extremely limited (Bishai *et al.*, 2003). In the case of Cape Town, this study recommends that pedestrian safety should be prioritised at all levels when introducing road safety interventions.

Thirdly, since percentage pedestrian and cyclist fatalities are higher than the respective percentage mode usage, prescribed interventions need to target the safety of these road users close to their destinations of travel rather than areas close to their homes. Fourthly, given the findings of Average Annual Fatalities (AAF) and Average Annual Fatalities (AAF) per 100 000 inhabitants per analysis district, it is important that both variables are considered when road safety analysis is performed at any level (aggregated or disaggregated). Fifthly, hazardous zones in the city continue to impact pedestrians crossing high-speed arterials, as previously found by Behrens (2002). The findings also suggest that driver behaviour and inadequate street lighting is a major problem in these areas.

Lastly, given the percentage of missing data, the City's road safety burden is underrepresented and that actual numbers may affect the interventions introduced. Therefore, in order to accurately represent the burden of road safety, data capturing in the field has to improve significantly. This is especially true for geocoded data that provide details on where fatalities are transpiring, and the areas that require infrastructure audits.

The scope of this study, due to time restrictions and dissertation requirements, did not include the determination of a detailed set of interventions based on the findings. However, the findings from this study determined the priority areas within the city when introducing interventions. The study can also assist in prioritising road users when implementing road safety interventions. Furthermore, the principles of this study can be implemented in countries with high fatality burdens, which mainly include low- and middle-income countries.

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Glossary

Fatality:	Person or persons killed during or immediately after an accident, or death within 6 days after an accident happened as a direct result of such accident
Fatalities/ 100 000 population:	A useful indication to determine the risk of dying due to a road traffic crash (World Health Organisation, 2015)
Hazardous zone:	An area with high concentration of fatalities
High-income district:	A district where majority of the households earn a monthly income of ZAR 8 000 or more based on the income distribution in the city
Low-income district:	A district where majority of the households earn a monthly income of less than ZAR 8 000 based on the income distribution in the city

List of symbols and acronyms

AADT	Average Annual Daily Traffic
AAF	Average Annual Fatalities
AT	Austria
BE	Belgium
BG	Bulgaria
CAR	Central African Republic
CT	Cape Town
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
DRC	Democratic Republic of Congo
EC	Eastern Cape
EE	Estonia
EL	Greece
ES	Spain
ESRI	Environmental Systems Research Institute
EU	European Union
FI	Finland
FPS	Forensic Pathology Services
FR	France
FS	Free State
GA	Gauteng
GDP	Gross Domestic Product
HIC	High-income Countries
HR	Croatia
HU	Hungary
IE	Ireland
iRAP	International Road Association Program
iPAS	Provincial Accident System
IT	Italy
ITF	International Transport Forum
KZN	KwaZulu Natal
LI	Limpopo
LIC	Low-income Countries
LMIC	Low- and Middle-income Countries
LT	Lithuania
LU	Luxembourg
LV	Latvia
MIC	Middle-income Countries
MP	Mpumalanga
MS	Microsoft
MT	Malta
NC	Northern Cape
NHTS	National Household Travel Survey
NL	Netherlands
NMT	Non-Motorised Transport
NW	North West
OECD	Operation of Economic Co-operation Development
PL	Poland
PT	Portugal
RO	Romania
RSA	Republic of South Africa
RTC	Road Traffic Crashes
RTI	Road Traffic Injuries
RTMC	Road Traffic Management Cooperation
RUA	Road User Approach
SAPS	South African Police Service
SE	Sweden
SI	Slovenia
SK	Slovakia
STA	Swedish Transport Administration
STP	Sao Tome and Principe
TAZ	Traffic Analysis Zone
UK	United Kingdom
US	United States
VZA	Vision Zero Approach
WC	Western Cape
WHO	World Health Organisation
ZAR	South African Rand

1. INTRODUCTION

1.1 Motivation for Study

Due to the legacy of Apartheid planning, fragmented and segregated urban development continues to exist in South Africa. This type of planning has resulted in the development of low density areas, usually in the peripheral areas of the cities, termed as "urban sprawl". A lack of adequate, private car competitive[1] public transport, to supply these areas has caused an average annual increase of 3.6% in motor vehicles registered in the country since 1990 (see Figure 1-1) (ITF, 2016). Majority of the vehicle owners have a monthly income of more than ZAR 6 000, which means that the economically and socially disadvantaged have to depend on walking as their primary mode of transport (Statistics SA, 2014). In Cape Town, for instance, Behrens (2005) found that when analysing walking as a main mode of transport, the percentage of users was 61% amongst low-income households compared to 9% amongst high-income households.

The World Health Organisation (WHO) (2015) reported that in low- and middle-income countries, the vulnerable road users in these countries – pedestrians, cyclists and motorcyclists – make up 52% of the road fatalities. In South Africa, the total number of fatalities have fluctuated between 1990 and 2015, reaching an all-time high of more than 15 000 road fatalities in 2006, as seen in Figure 1-1. The most vulnerable group, amongst these fatalities, was found to be pedestrians, who accounted for 40% of recorded transport related deaths in 2003 (Matzopoulos, 2004). Mabunda *et al.* (2008) deduced that for the 2001-2004 period, 7 433 pedestrian deaths were recorded in four major cities of South Africa – Johannesburg, Cape Town, Durban and Pretoria, the majority of which occurred during the weekends.

In the case of the Western Cape, and in particular Cape Town, the road safety burden has been decreasing in recent years, due to prolonged investments in road safety measures (Vanderschuren *et al.*, 2017). However, this decrease has stagnated lately and further analysis is required to unpack the road fatalities that are occurring on a district level in order to articulate informed interventions.

[1] Studies by Hitge and Vanderschuren, 2015 show that travel time by public transport is usually 1.5 times that of a private car

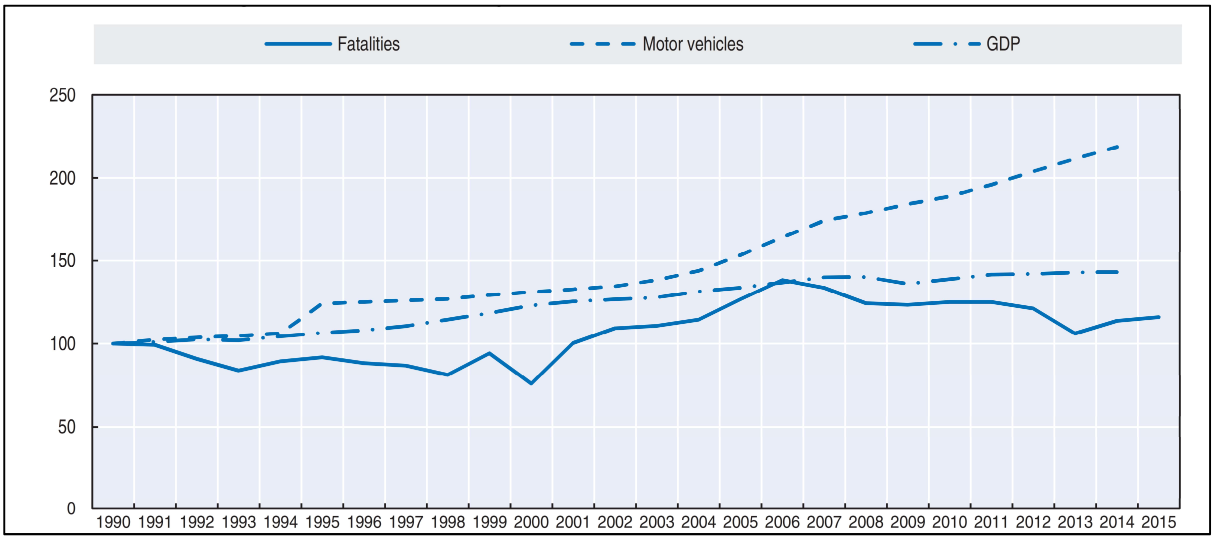

Figure 1-1: Road safety, traffic and GDP trends in South Africa (index 1990 = 100)

Source: World Bank for Gross Domestic Product (GDP; constant prices) in ITF, 2016: 460

1.2 Background of Study

The Departments of Civil Engineering at the Universities of Stellenbosch and Cape Town were appointed by the Cape Higher Education Consortium (on behalf of the Western Cape Government) to develop a *Road Safety Implementation Programme for the Western Cape*. The project involved analysis of the Forensic Pathology Services (FPS) and the Provincial Accident System (iPAS) data to determine the road safety response that would be required at a provincial level. Additionally, the project included a specific analysis for Cape Town, due to its metropolitan status in the province. This particular analysis will be examined in this study to determine the road safety status quo for Cape Town districts.

1.3 Overall Aim of Study

This research aims to ***Identify the localised road safety burden in Cape Town based on the road fatalities for the period 2011-2015***. Since local factors, such as household income and, consequently mode usage play a major role in road fatalities, it is important to determine the road user group affected in different parts of the City for effective interventions to be realised. As a result, this study aims to identify the hazardous areas within the city and the impacts they have on the five road user groups – drivers, cyclists, motorcyclists, pedestrians and passengers. Furthermore, the five-year period analysis would ensure that fatalities are analysed over a significant period and consider various variations.

1.4 Objectives of Study

In order to meet the overall aim of the study, the following research questions need to be answered:

- What is the current road safety status quo at a Worldwide, African, and National level?
- In terms of total fatalities in the five years analysed, what is the relative impact on each road user group?
- Is the percentage death toll for the various road user types positive or negative, when compared to percentage mode usage for the various districts?
- How do the Average Annual Fatalities (AAF) and the Average Annual Fatalities (AAF) per 100 000 population of the Cape Town analysis districts compare to each other?
- How does the Average Annual Fatalities (AAF) per 100 000 population of the Cape Town analysis districts compare to World and African Averages?
- Which vehicle types pose the greatest threat to the five road user groups on the road?
- Where are the high-risk zones in Cape Town located?
- Based on the literature available on road safety best practices, what localised interventions can be prescribed to reduce the fatalities in high-risk zones?

Furthermore, to answer the above questions, the following tasks will be performed in this dissertation:

- Determine the total number of fatalities for each road user group in each district
- Determine the percentage death toll and the percentage mode usage for the five road user groups
- Determine the Average Annual Fatalities (AAF) of the districts
- Determine the Average Annual Fatalities (AAF) per 100 000 population of the districts
- Identify the type of vehicle involved in the fatalities
- Identify the hazardous zones
- Prescribe measures, based on best practices, for the hazardous zones identified.

1.5 Scope and Limitations of Study

As mentioned previously, this study uses data derived from the *Road Safety Implementation Programme for the Western Cape* study performed. As a result, the following limitations with this study are noted:

- **Time available:** This study is conducted in partial fulfilment of a MEng Degree in Transportation studies. Since this is a minor dissertation, a comprehensive study was not performed in order to collect primary on-site data. The time constraints also limited a comprehensive analysis of the localised interventions that would be required to reduce the overall number of fatalities in the hazardous zones of the City.
- **Data sources:** The data used in this study was obtained from various sources (described in the Methodology section). The verification of this data was not possible though, especially in the case of fatality locations where certain errors were either identified and corrected, or omitted. It is widely accepted, however, that the agencies responsible of capturing the fatalities data in the country have improved their data collection methods, though, gaps are still present. Despite this, the data is sufficiently reliable and can be used to perform analysis and answer the questions posed in the previous section of this chapter.

1.6 Study Area

The 2013 National Household Travel Survey (NHTS) disaggregated Cape Town into 18 Traffic Analysis Zones (TAZs) and these TAZs were defined as the ‘analysis districts’ of Cape Town in this study. One of the aggregated TAZs i.e. the Mitchells Plain district, comprised of the Gugulethu Township in the National Survey. However, the township was analysed separately in this study, due to the interesting findings within the area. As a result, this study involved the usage of 19 districts to disaggregate Cape Town, shown in Figure 1-2.

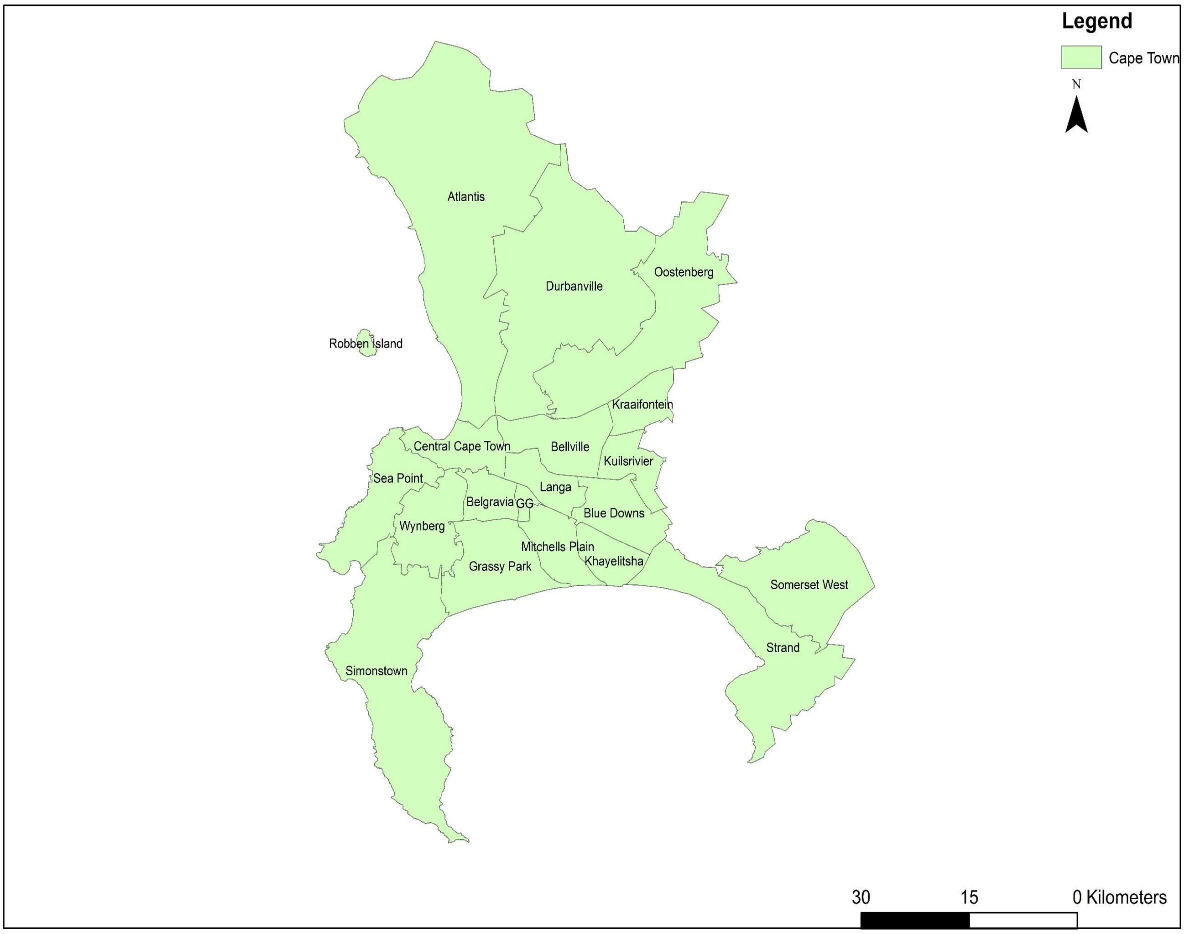

Figure 1-2: Study area showing Cape Town districts

Note: GG represents Gugulethu

1.7 Organisation of Dissertation

Henceforth, this dissertation will be divided into four chapters. Chapter Two describes the literature review of road safety at the Global, African and National level together with a brief description on road safety best practices around the World. Chapter Three describes the methodology adopted in this study, the mathematical approach of this study and a short description on Cape Town as a case study. This Chapter also discusses the analysis performed in this study while Chapter Four describes the findings of the analysis. Lastly, Chapter Five explains the conclusions drawn up from the findings, the implications of these findings and describes further applications of the study.

2. ROAD SAFETY STATUS QUO

2.1 Introduction

In this Chapter, the existing road safety literature on a Global, African and National (South Africa) level are investigated in different sections. On a Global level, a general background is provided on road safety challenges around the world, before discussing the current situation in Low- and Middle-Income Countries (LMIC) and High-Income Countries (HIC), while also describing the reasons for the general trends observed. This section also discusses the road safety best practices in both types of countries. Similarly, on an African and National level, the fatality trends are discussed together with general causes of the high fatality rates observed.

2.2 The Global Situation

2.2.1 Background

The WHO (2015) states that road traffic injuries claim more than 1.25 million lives each year, which equals to approximately 3 470 deaths each day. The report further states that road traffic injuries are the ninth leading cause of death worldwide and the leading cause of death among young bread earners aged 15-29 years. Estimations suggest that by 2030, road traffic injuries will be the seventh leading cause of death around the world. Furthermore, the WHO estimates that 20 to 50 million people each year are either injured or disabled through road traffic crashes. It is worth noting, though, that road deaths have plateaued from 2007 to 2013 despite the increase in population and motorisation during this period.

In addition to impact on human life, crashes and accidents also place a heavy burden on the country's economy because of the high costs involved. These costs include "medical costs, production losses, human losses, property damage, settlement costs and more" (Wegman, 2016). Literature studies from Wegman (2016) and WHO (2015), deduced that these costs vary from 1% to 5% of GDP, whereby the impact on LMIC varies from 1 to 3%, and 2.2 to 4.6% in the case of HIC.

When comparing the risk of dying due to a road traffic crash, rates per 100 000 population, also known as fatality rates, are a useful indication. Whilst the global fatality rate for road traffic deaths is 17.4 per 100 000 population, there is an imbalance in terms of income of countries, with rates from LMIC more than twice that of HIC (WHO, 2015) as seen in Figure 2-1. This variation between LMIC and HIC was also observed by Kopits and Cropper in 2005, who estimated that, whilst the global death toll will increase by 66% between 2000 and 2020, the increase will not be seen across all countries. In fact, in HIC, a decline of approximately 28% will be observed, while an increase of 80% will be observed in developing countries, with fatalities in China and India increasing by 92% and 147%, respectively. These numbers suggest that the risk of dying in LMIC is higher than HIC, which is astounding considering the fact that they account for 82% of the population, but only account for 54% of the world's registered vehicles (WHO, 2015).

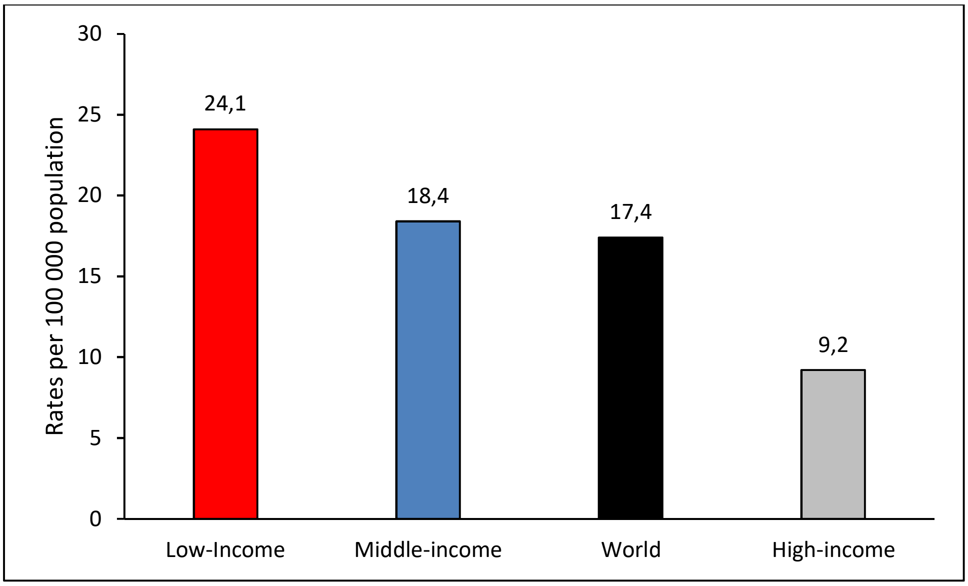

Figure 2-1: Fatality rates per 100 000 population by income status

Data Source: World Health Organisation (2015)

The HIC have made enormous strides in recent years to reduce these death tolls with various safety models adopted in Sweden, UK, Netherlands and Australia (Hughes *et al.*, 2015). However, a different picture emerges in LMIC which, only in recent years, have initiated the process of designing road safety strategies and implementing action plans (Wegman, 2016). The current situation of road safety in both LMIC and HIC will be discussed in the next few subsections, before unpacking the best practices that these two types of countries have adopted to reduce overall death rates.

2.2.2 Low- and Middle-Income Countries

The economic costs of road crashes vary disproportionately when comparing LMIC in different regions and have been estimated to be as much as US$3.7 billion in Africa, US$24.5 billion in Asia, US$ 19 billion in Latin America and Caribbean, US$7.4 billion in the Middle East, and US$9.9 billion in Central and Eastern Europe (Jacobs *et al.*, 2000). These amounts are substantially higher than the total development assistance received annually by LMIC (Naci *et al.*, 2009). Additionally, studies show that road traffic injury patients in LMIC occupy 30-70% of orthopaedic beds in hospitals (Mohan, 2002).

In LIC, national analysis has revealed that the budgetary expenditure on road safety, at all levels of government, is extremely limited (Bishai *et al.*, 2003). It is also common that majority of the population in these countries fall in the low-income category. As a result, Road Traffic Injuries (RTIs) can lead to a heavy financial burden, which can permanently affect the health of family members (Mohan, 2002). This finding suggests that the allocation of resources has to be carefully managed in these countries in order to protect the most vulnerable group. Therefore, if the most vulnerable group is private car users, a large portion of the road safety budget should be allocated to interventions that target a reduction in fatalities of this type of user (Naci *et al.*, 2009), for example, improved expressways. However, if the most vulnerable group are Non-Motorised Transport (NMT) users, an appropriate intervention might be the provision of safe crossing facilities.

Accurate data is difficult to obtain in many countries, since there is widespread under-reporting and, in many cases, incomplete recording of road traffic deaths (Hofman *et al.*, 2005; Naci *et al.*, 2009; ITF, 2016 and Ameratunga *et al*., 2004). However, using data from multiple sources, Naci *et al.* (2009) was able to deduce the distribution of road traffic fatalities for four user groups from 76 countries based on the income status of countries (see Figure 2-2). The study also performs a similar analysis for HIC countries, however, the results for countries falling under this income category will be discussed in the next subsection.

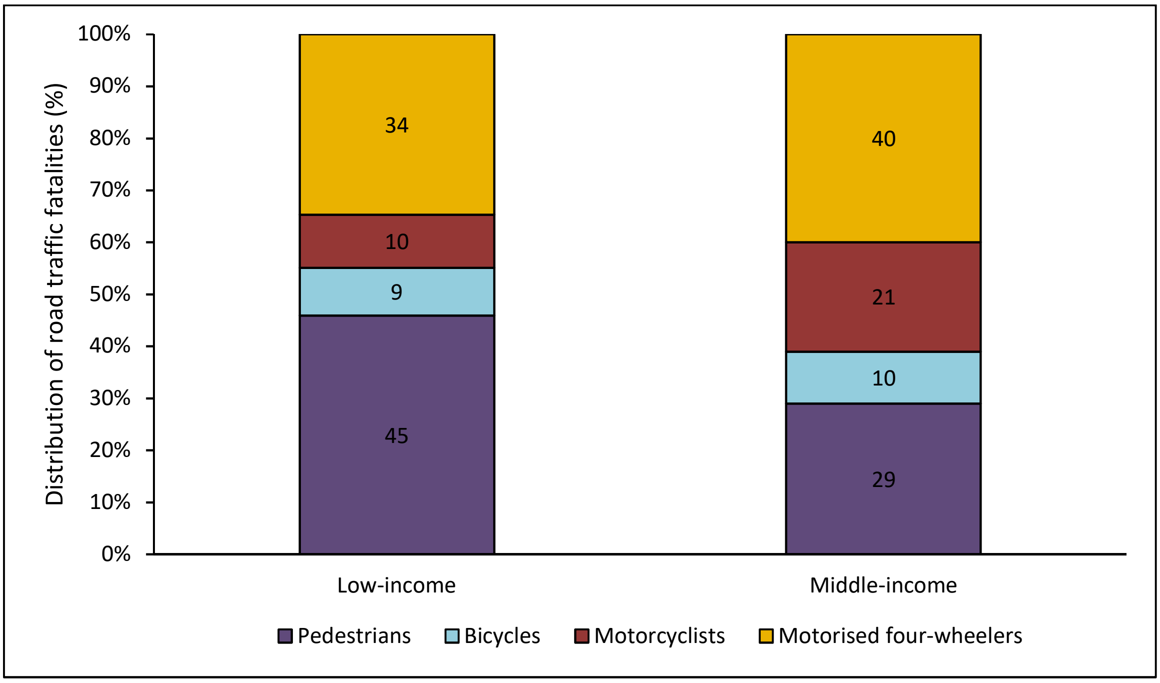

Figure 2-2: Road traffic fatalities by road user group in low-income and middle-income countries
Data Source: Naci *et al.* (2009)

The results show that 45% of road traffic fatalities in LIC are among pedestrians, compared to 29% in MIC. The data also estimates that 21% of fatalities in MIC constitute of motorcyclists. When considering motorised four-wheelers, the percentage users affected are approximately similar at 40% and 34% for MIC and LIC, respectively. The majority of road traffic deaths affecting the motorised four wheelers in these countries are mainly passengers of public transport (Naci *et al.*, 2009). If the estimates of road traffic deaths by WHO (2008) are used, as seen in the study by Naci *et al.* (2009), a total of 227 835 pedestrians die in LIC and 161 501 die in MIC (see Figure 2-3). When considering pedestrians, motorcyclists and cyclists, 324 032 (66% of road user deaths) and 334 140 (60% of road user deaths) die in LIC and MIC, respectively. This finding confirms that these three road users are the most vulnerable group in LMIC. Literature from various sources also infer that pedestrians, motorcyclists and cyclists are the most vulnerable road users in LMIC, since they make up the majority of road user fatalities in these countries (see, for instance, Nantulya et al., 2003; Mohan, 2002 and WHO, 2015). The results of the total number of deaths for each road user is shown in Figure 2-3.

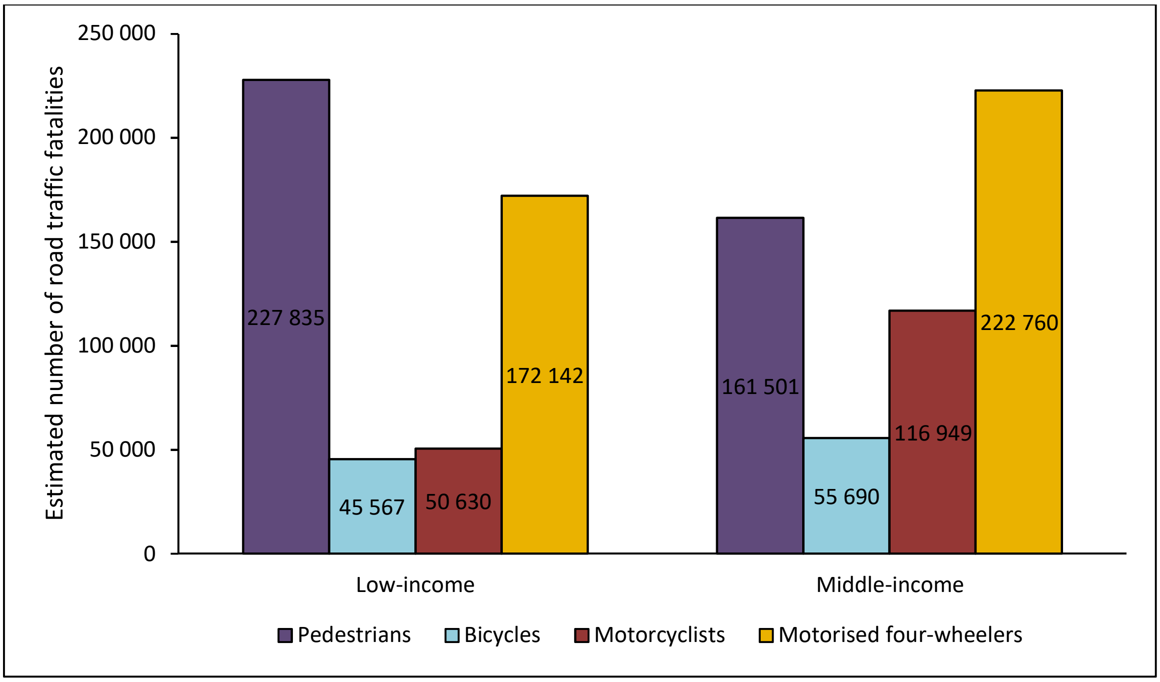

Figure 2-3: Estimated annual road traffic deaths by road user groups

Data Source: Naci *et al.* (2009)

In the case of four wheeler vehicles, the majority of fatalities that impact these road users occur during the use of public transport (Naci *et al.*, 2009), which is mainly used by low socio-economic groups in these countries. For example, in Lagos (Nigeria), commuter buses are referred to as "moving morgues – *molue*", due to the risk they pose to passengers (Nantulya and Reich, 2002). Pedestrians, cyclists and motorcyclists also fall under the same socio-economic group in these countries where they form the majority of the traffic (Mohan, 2002). This suggests that there is a lack of social equity when RTIs are concerned.

When discussing RTIs in LMIC, it is important to look at the two countries that comprise of $^1/_3$ of the world's population and fall under this income category – China and India (Exner, 2011). As mentioned previously, Kopits and Cropper (2005) had estimated that road fatalities in India and China will increase by 92% and 147% by 2020, respectively. In the case of India, it was estimated that 183 600 deaths occurred in 2005 nationally, which corresponds to 2% of all road deaths (Hsiao *et al.*, 2013). The mortality rate was greater for men than women and higher in urban areas than in rural areas. Furthermore, similar to results from LMIC, vulnerable road users consisted of majority (68%) of RTI deaths. A striking feature of the study showed that 35% of deaths occurred en-route to the hospital, which indicates that by improving post-crash conditions, a significant reduction can be achieved in the number of annual fatalities (Vanderschuren and McKune, 2015). The WHO (2015) estimated that on 2013, 207 551 road traffic fatalities occurred in India, which is a 13% increase to the value of 183 600 in 2005.

In China, estimations revealed that RTIs killed approximately 261 367 people in 2013 (WHO, 2015). Traffic related injury consisted of 32.4% of all injury deaths, higher than all intentional and unintentional injuries that lead to death (Wang *et al.*, 2008). Similar to India, the majority of road traffic fatalities occurred in men (71.9%) and unlike India, to persons living in rural areas (67.4%) (Lin *et al.*, 2013). Although the literature did not discuss the variation of RTIs among various road user groups in China, studies from Naci *et al.* (2009) and Wang *et al.* (2008) state that, similar to LMIC in general (see Figure 2-2), pedestrians, cyclists and motorcyclists are the most affected group in the country.

A number of studies suggest various reasons as to why 84% of road traffic deaths occur in LMIC (WHO, 2015). Mohan (2002) states one of the reasons is that people in these countries tend to occupy households on either side of high-speed expressways and have to cross the expressway in order to interact with each other. Designated over- or under-passes that reroute their path have failed to prevent people from crossing expressways, because these over/underpasses are generally longer and are often unsafe (Ameratunga *et al.*, 2004). Studies from Brazil, Uganda and Mexico have shown similar trends (Mutto *et al.*, 2002; Fourjah, 2003 and Híjar *et al.*, 2003). A study by Nantulya and Reich (2002) noted that the growth in motor vehicle numbers, poor enforcement of traffic safety regulations, inadequacy of public health infrastructure and poor access to health services all contributed to the high burden of fatalities in developing countries. Additionally, it has been found that high speed limits on urban roads have a substantial impact on fatalities, since high speeds require a greater stopping distance, resulting in increased stopping times (Wilmot and Khanal, 1999).

With the above in mind, it can be concluded that the danger posed to pedestrians, cyclists and motorcyclists, is comparatively higher in LMIC. Therefore, with the limited budget spent on road safety in these countries, the budget has to be allocated on interventions that aim to protect this particular group. Unfortunately, that is not the case in developing countries, which continue to prioritise motorisation (Vanderschuren *et al.*, 2017). Since, little evidence is available on LMIC that has successfully reduced road traffic fatalities, interventions that have been successful in HIC have to be analysed (Mohan, 2002 and Ameratunga *et al.*, 2004). However, the context is crucial in implementing these measures since a number of variations exist in travel patterns, income groups and mode usage between the two types of countries. In the case of travel patterns and accidents, the variations between less motorised countries and HIC are not only present today but they are also substantially different from those prevailing in HIC at a comparable stage of development in the past (Mohan, 2002).

2.2.3 High-Income Countries

As described previously, HIC have a significantly better performance with regards to road fatalities than LMIC. In fact, while Kopits and Cropper (2005) predict an increase in road fatalities of 66% globally by 2020, the prediction is different for HIC where a decrease of 28% or 1 fatality per 10 000 population is expected. Peden *et al*. (2004) compared the performance of HIC to LMIC for the different continents (see Figure 2-4). The results concur that HIC, in every continent, except for Eastern Mediterranean, have a lower mortality rate than LMIC in the same continent.

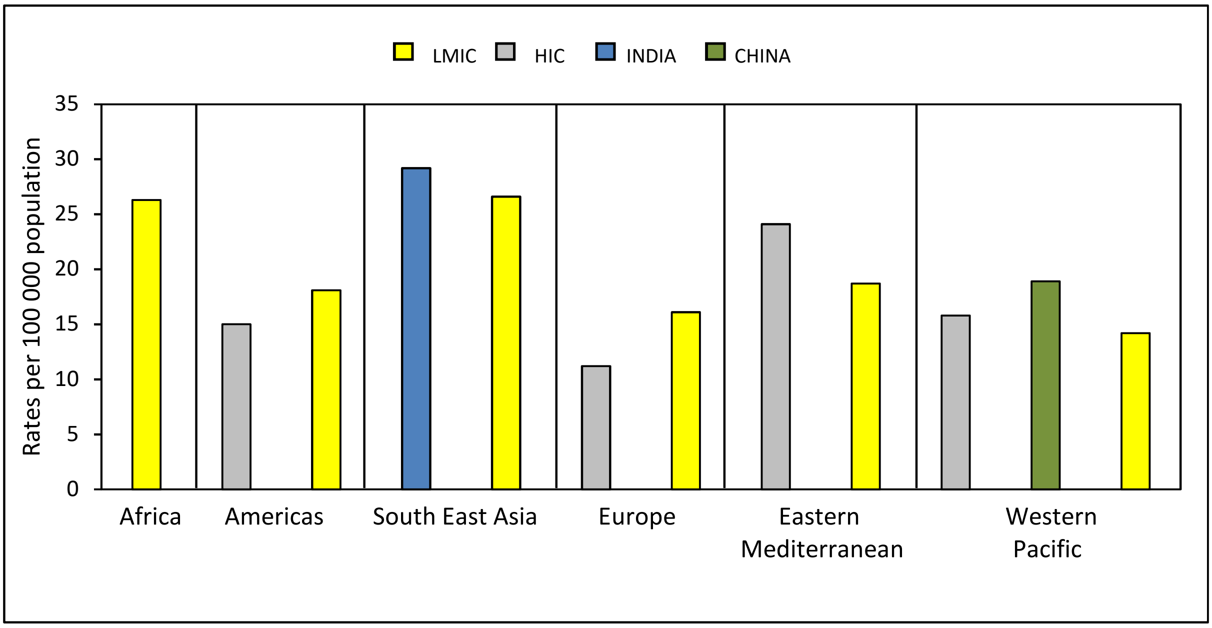

Figure 2-4: Global mortality rates due to road crashes in 2000

Data Source: Peden *et al.* (2004)

In addition to this, a variation is also observed in the road users affected by fatalities in these countries. As seen previously, pedestrians, cyclists and motorcyclists face a higher risk compared to private car users in LMIC. However, in HIC, the opposite is true, with private car users having a higher risk of dying and are consequently considered as the vulnerable group in these countries (Naci *et al.*, 2009). Figure 2-5 takes an average of the distribution of road traffic fatalities by road user group in LMIC (as seen in Figure 2-2) and compares this to HIC. As seen in the Figure 2-5, pedestrians, cyclists and motorcyclists make up 37% of the total road traffic fatalities in HIC, which is substantially less than LMIC where the same group makes 63%, on average, of the total road traffic fatalities. The vulnerable road user in these countries i.e. motorised four wheelers, are at a higher risk at 63% compared to 37% in LMIC.

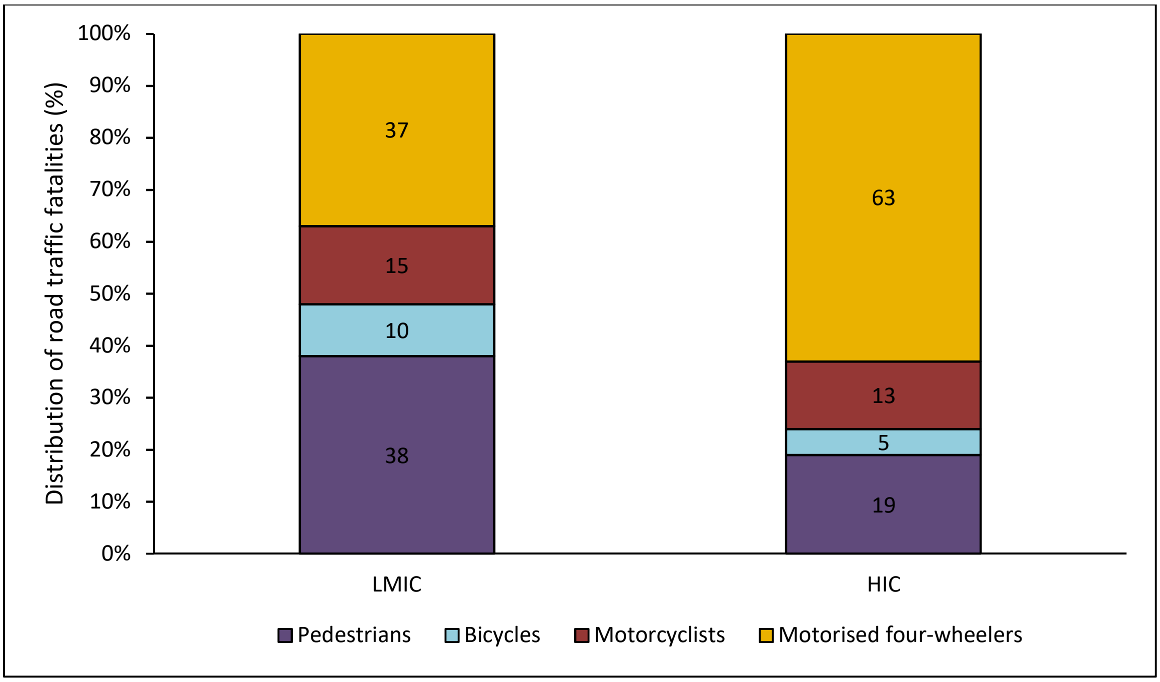

Figure 2-5: Distribution of road traffic fatalities by road user group and by income category Data Source: Naci *et al.* (2009)

When considering the absolute numbers, a total of 118 750 road users die annually in HIC compared to 329 086 on average that die in LMIC (as described previously), respectively. This value deduces that annual fatalities in LMIC are more than double the annual fatalities in HIC. Out of 118 750, some 75 000 fatalities occur among motorised four-wheelers and the remaining 43 750 occur among pedestrians, cyclists and motorcyclists. As predicted by Kopits and Cropper (2005), a distinction is also observed in the variation of annual fatalities in HIC and LMIC with HIC managing to reduce the fatality burden with the use of various interventions.

The European Union (EU) in 2001, for example, set out an ambitious objective of halving the yearly number of fatalities between 2001 and 2010 (European Transport Safety Council, 2011). Figure 2-6 shows the fatality change[2] of each of the 27 EU countries during the period and the average change within the EU. As a whole, EU countries reduced road fatalities by an average of 43%, falling slightly short of the 50% target. Germany, France, the Netherlands and Portugal met the EU's target while countries such as Latvia, Estonia, Luxemburg, Spain, Slovenia, Sweden and Lithuania, achieved greater reductions i.e. above the EU target. Overall, all countries reduced the total number of fatalities between 2001 and 2010.

[2] Percent change in the number of fatalities is used, generally, as an indicator to compare the road safety development between countries whereby a higher reduction indicates a better performance.

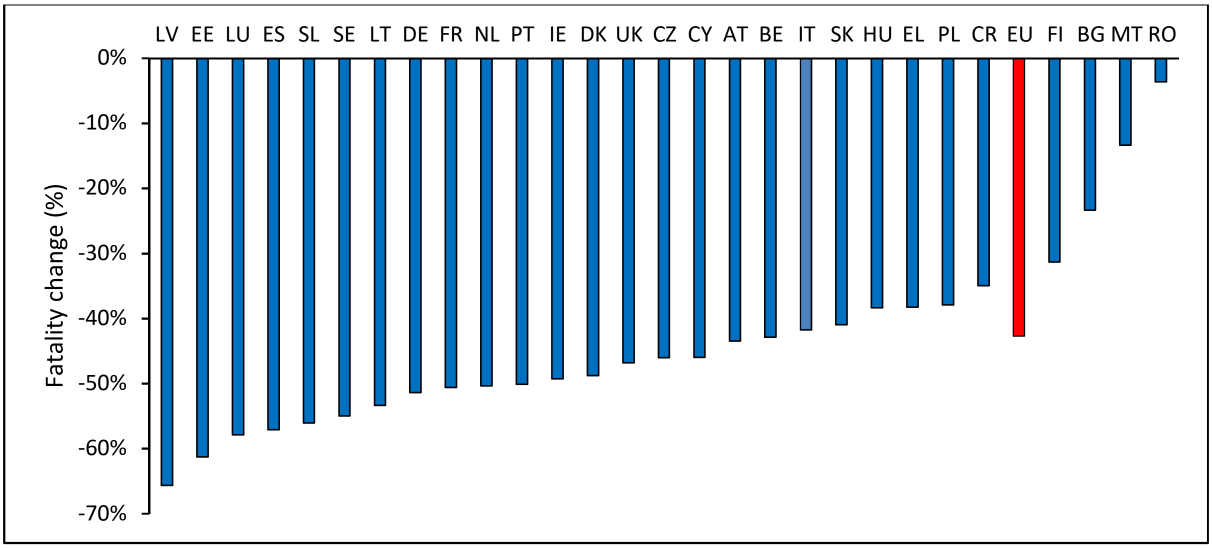

Figure 2-6: Fatality change of 27 EU countries between 2001 and 2010

Data Source: European Commission (2016)

Evans (2014) observed a similar trend when comparing the traffic fatality reduction of the United States and 25 other countries, including Great Britain, Canada, Australia, the Netherlands, Japan, Germany and other countries falling in a similar income bracket. The United States, Great Britain, Australia and Canada achieved a reduction of 36.6%, 70%, 63.7% and 65.5%, respectively, in the number of annual traffic fatalities between 1979 and 2011. The European countries – Germany (74.2%), France (70.9%), the Netherlands (68.9%), Spain (69.5%) and Portugal (67.5%), have also significantly reduced the annual traffic fatalities recorded during the same period.

Furthermore, some of the countries mentioned above, which are part of the Organisation of Economic Co-operation and Development (OECD), record less than 10 road traffic fatality rates per 100 000 population annually (Peden *et al.*, 2004). Among these, The Netherlands, Sweden and Great Britain have the lowest rates per 100 000 population (see Table 2-1). The decline observed previously and high rates of fatality reduction suggest that integrated strategic programs, in these countries, produce marked declines in fatalities and, by extension, injuries and accidents. In Sweden and The Netherlands, programs entitled "Vision Zero" and "Sustainable Safety" that aim to reduce the fatalities further, have been introduced.

Table 2-1: Road traffic fatalities in selected countries or areas in 2000

Country or area	Fatalities per 100 000 population
Australia	9.5
European Union	11.0
Great Britain	5.9
Japan	8.2
Netherlands	6.8
Sweden	6.7
USA	15.2

Data Source: Peden *et al.* (2004)

Vision Zero is a long term strategy that aims to introduce incremental system improvements with an ultimate goal of no fatalities or severe injuries through road traffic crashes in Sweden (Peden *et al.*, 2004). Pedestrian safety is at the forefront of this policy with significant investment in managing speed where there is a conflict of vehicles or vehicle users. Vehicle speeds are limited to 30 km/h where potential vehicle-pedestrian conflicts exist or, alternatively, cars and pedestrians are spatially separated. The reason for choosing 30 km/h is that studies have shown that at this limit, pedestrians and cyclists are more likely to survive a collision (Swedish Transport Administration (STA), 2014). In total, about 17 lives per year were saved since the change in speed limits (Vadeby and Forsman, 2017).

Similar to the "Vision Zero" initiative, The Netherlands introduced the "Sustainable Safety" program in in 1998, with an underlying premise "man as the measure of all things" (Peden et al., 2004). The program is centred on speed management whereby all urban roads would be converted to perform a "residential" function with a speed limit of 30 km/h, similar to Vision Zero. The speed limit was based on the 'Woonerf' concept where motorised traffic is limited to the speed of pedestrians and cyclists. In certain projects in The Netherlands, where the 'Woonerf' concept was implemented, 70% reductions in injury accidents were reported (Wegman and Elsenaar, 1997). By 2001, 50% of the urban road network was converted into a 30 km/h zone.

Great Britain, in addition to other HIC discussed in this subsection, have also successfully reduced fatalities using various interventions. These countries have also reduced the impact of fatalities on pedestrians, cyclists and motorcyclists, successfully (see Figure 2-5). Since the same user groups are the most affected group in LMIC, it is important to extract successful interventions that have assisted these countries in protecting them. In the next subsection, best practices from these countries will be discussed. In order to ensure that the context of problems in LMIC are considered, the next subsection will also draw from studies in developing nations that discuss the current challenges and provide successful interventions.

2.2.4 Road Safety Best Practices

Road safety strategies have continued to evolve over the years (Hughes *et al.*, 2016). The earlier approach to road safety, known as the Road User Approach (RUA), focused on human error as the main cause of road accidents, which meant that an individual road user was solely responsible when a crash occurred (Peden *et al.*, 2004). As Larsson *et al.* (2010) noted, this approach was based on the premise that studies by Treat *et al.* (1979), for example, found that 95% of all road accidents were the result of human error. The approach also has a legal basis, whereby every road user has a legal responsibility to prevent the occurrence of road accidents (Tingvall and Haworth, 1999). Therefore, if an accident does occur, at least one road user is held responsible for the incident and the legal system can act accordingly (Larsson *et al.*, 2010).

The prevention measures in the RUA approach, hence, focused on changing road user behaviour through regulations and education in order to align road users towards the system so that accidents would not occur (Mackay and Tiwari, 2001). This approach was, however, limited because it did not take into account that humans make mistakes. To tackle this, the Swedish government adopted the Vision Zero Approach (VZA) that allowed for this limitation by assuming that crashes would continue to occur, but the key was to manage vehicles, road infrastructure and speeds to minimise the risk of a death or serious injury (Langford and Oxley, 2006 and Larsson *et al.*, 2010). In contrast to the RUA approach, the VZA considers road safety to be a shared responsibility between the designers, administrators, professional users of the road transport system and the road users (STA, 2014). Because VZA adopts this logical approach to road safety, which has yielded positive results, the WHO (2015), therefore, recommends that all countries adopt this method.

However, the adoption of the conceptual VZA model requires a level of change in institutional mind-set that cannot be understated (Johnston, 2010). Also, the model cannot be adopted effectively without political and community readiness. Hence, Johnston (2010) recommends four C's: Constituency, Commitment, Cooperation and Coordination, that would be key to implementing the best practice VUA approach. These are explained as follows by the author:

- *Constituency:* The public has to demand action in order to force the government to invest resources into the program. Furthermore, constituency has to be embedded into the culture for sustained progress rather than a single intervention during the "protest".
- *Commitment:* The politicians at all government levels, including the president, need to exhibit the political will to achieve success from the program. This is obviously dependent on constituency with the behavioural norms of the society influencing interventions introduced.
- *Cooperation:* Measures implemented in a road safety program requires meaningful cooperation for a positive impact to be observed.
- *Coordination:* Together with cooperation, coordination is crucial to integration and interaction across institutional efforts (Wegman et al., 2008).

From this, it can be gathered that considerable effort is required to change the approach in the institutional mind-sets of developing countries towards the VZA model. In addition to this, developing countries also need to align their safety priorities towards protecting Vulnerable Road Users (VRUs) that are impacted in these countries, especially pedestrians. This argument stems from the fact that (a) pedestrians are the most impacted road user group among the VRUS in developing countries (Vanderschuren and Zuidgeest, 2017) and (b) walking is the main mode of transport in developing cities (Watson, 2015). For instance, in Dar es Salaam (Tanzania) and Nairobi (Kenya) it was found that nearly half the trips are made entirely on foot with only 10% of trips being made on private motorised transport (Servaas, 2000).

In developed countries, for instance, certain urban designs have aimed at protecting pedestrians by either integrating[3] them with, or separating[4] them, from automobiles. Such designs have yet to be seen in developing countries where social inequality increases through increase in motorised transport. The high number of pedestrian fatalities can also be attributed to increased motorisation in developing countries. Vanderschuren and Zuidgeest (2017) note that this is because increase in vehicle numbers and size increases the exposure to the crash risk. A study in Florida by Lee and Abdel-Aty (2005) also concurred with this observation when analysing pedestrian crashes at intersections. The study found that the rate of pedestrian crashes increased rapidly with an increase in Average Annual Daily Traffic (AADT)[5] up to an AADT of 30 000. Beyond AADT of 30 000, the rate of pedestrian crashes reduced since, as the authors noted, congestion set in and the vehicles were forced to drive at lower speeds. Gårder (2004) also found that wider roads and high speeds lead to more crashes. Hence, it can be inferred that arterials and major collectors, with these attributes, have a higher percentage of crashes.

In terms of traffic-related injury prevention, Haddon (1983) famously developed a road safety matrix, based on the systems approach, that identifies the risk factors before, during and after a crash in relation to the person, vehicle and environment (see Table 2-2). Using the matrix, each phase of the crash – pre-crash, crash and post-crash – can be analysed for human, vehicle and environmental factors (Mohan, 2006). After identifying and analysing the various factors involved in each cell of the matrix, both short-term and long-term counter measures can be developed and prioritised for implementation.

Table 2-2: Haddon road safety matrix

		FACTORS		
PHASE GOALS		***Human***	***Vehicle and equipment***	***Road environment***
Pre-crash	Crash Prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design/layout Speed limits Pedestrian facilities
Crash	Injury preventing during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash protective roadside objects
Post-crash	Sustaining life	First-aid set Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Source: Haddon (1983)

In other countries, including South Africa, the 4 E's strategy has been adopted: Enforcement, Education, Engineering and Evaluation (Vanderschuren and Zuidgeest, 2017). According to Vanderschuren (2016), these can be described as follows:

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[3] See, for instance, the 'Woonerf' concept that integrates pedestrians and automobiles by forcing vehicles to drive at pedestrian speeds (15 km/h) and behave according to pedestrian rules (Behrens, 2002a).
[4] See, for instance, the 'Radburn' superblock design that separates pedestrians and automobiles completely in order to prevent any conflicts between the two road users thereby reducing fatalities (Behrens, 2002a).
[5] AADT is the total volume of traffic over a year divided by 365 days.

- *Enforcement:* For safer roads, road users need to abide by the traffic laws of the country. The focus should be on enforcing these laws consistently.
- *Education*: This component includes educating road users about their environment and their bad behaviour that can create a crash risk. In the case of the environment, the education component may include teaching pedestrians about the benefits of using pedestrian bridges when crossing highways. In the case of bad behaviour, measures may include educating drivers on the benefits of seat belt use.
- *Engineering:* Similar to education, two factors need to be considered in terms of engineering for road safety. Firstly, the standard of vehicles (tyre pressure, roadworthiness) used on the road has to be improved. Secondly, the infrastructure provided needs to ensure safety of all road users.
- *Evaluation:* In order to prevent fatal road crashes, roads where crashes generally occur, need to be evaluated. These evaluations include analysing the fatalities data in the locations for trends and causes of crashes. Furthermore, performing road audits to determine the localised problem and to identify the solution. This step defines the analysis performed in this study.

The UN also identified the five pillars of road safety that can successfully reduce the road safety risk, in the Decade of Action for Road Safety 2011-2020. These five pillars include: road safety management (P1), infrastructure (P2), safe vehicles (P3), road user behaviour (P4) and post-crash care (P5) (UN, 2010). Vanderschuren and Zuidgeest (2017) developed a matrix that combined the three strategies – Haddon's matrix, 4 E's strategy and the five pillars of road safety – to develop road safety measures that would potentially reduce fatal crashes in LMIC especially in Africa (see Table 2-3).

Table 2-3: Haddon's crash theory, the five pillars and the four E approach for road safety

	Pre-crash	***Crash***	***Post-crash***
Enforcement	• Policy, strategy and legislation P3 • Policing P3 P4	• Speed limits P2 P4	• Road safety management P1 • Congestion management P1
Education	• Safer road users P4 • Information provision P4 • Attitude based campaigns P4 • Impairment awareness • Handling/driver training P4	N/A	• First-aid set P5 • Access to emergency services P5
Engineering	• Safer roads and mobility P2 • Safer vehicles P3 • Speed management/limits P1 • Road design P2 • NMT facilities P2	• Restraints/safety devices P3 • Crash protective design (including for pedestrians) P3 • Crash protective roadside objects P2	• Ease of access to crash P5 • Fire risk control P5

Source: Developed by Vanderschuren and Zuidgeest (2017) using Haddon matrix (1983)[6]

[6] In the matrix (see Table 2-3), each column represents the three crash incidents -pre-crash, crash and post-crash - and each row represents the 4 E's. In each cell various measures are recommended, which have a designation of P1 to P5 representing the five pillars of road safety.

Table 2-3 (continued)

	Pre-crash	*Crash*	*Post-crash*
Evaluation	• Road safety audits P2 Time to collision	Phone or on-board data analysis	• In-depth crash investigation • In-depth stats analysis • Policy, strategy and legislation P5

Source: Developed by Vanderschuren and Zuidgeest (2017) using Haddon matrix (1983)

For each column, a short description is provided below on the 4 E's:

a) Pre-crash

The measures recommended in this column aim to prevent occurrence of accidents. These measures are as follows:

- **Enforcement:** The road-worthiness of vehicles leads to a large number of accidents in African countries (Vanderschuren and Zuidgeest, 2017). The problems found with many vehicles include, but are not limited to, faulty brakes, lights, tyre pressure. Hence, policies adopted in the country need to ensure that all vehicles on the road are registered and have licenses.

  Nantulya and Reich (2002) also state that poor enforcement of traffic laws is one of the major causes of road fatalities in African countries, with corruption playing a further major role in these countries. For instance, in Lagos, bus owners secure road worthiness certificates despite having their vehicles banned initially (BBC News, 2001). These laws include the use of seat belts for drivers and the use of helmets for cyclists and motorcyclists. Studies have found that fatalities are less common with drivers that use seat belts and cyclists or motorcyclists that use helmets (see, for instance, Latimer and Lave, 1987; Thompson *et al.*, 1999 and Tsai and Hemenway, 1999).

- **Education:** As mentioned previously, education plays a major role in teaching road users about the road environment or correcting bad behaviours. For instance, in Indonesia, a study found that only 55% of motorcyclists wore helmets correctly (Conrad *et al.*, 1996). An awareness campaign, in this case would assist in educating motorcyclists on the correct use of helmets.

  There are also cases where road users are not aware of the benefits of provided infrastructure. A study in Kampala, Uganda found that only 6.9% of pedestrians thought that an overpass provided a safe means of crossing high-speed arterials (Mutto *et al.*, 2002). This finding suggests that providing safe infrastructure has to go hand-in-hand with public engagement on the benefits of the provided infrastructure.

- **Engineering:** Road design in African countries is based on US design standards and these are car-oriented designs that lack NMT planning (Vanderschuren and Zuidgeest, 2017). However, unlike the US where the majority are car users, majority of road users in LMIC are pedestrians, as mentioned previously. Consequently, the road designs adopted should be pedestrian-oriented, which include: reduced speed limits, providing NMT infrastructure and improving road designs

There are challenges, though, when adopting some of these measures. In South Africa, for instance, Steunenberg and Sinclair (2014) found that there is resistance from professionals in regards to adopting reduced speed limits. The authors suggest that the findings from the study reflect that there is a lack of knowledge on how speed limits work and how they have worked in the case of other countries. However, in 2017, South Africa did approve new speed limits for roads passing by residential areas (BusinessTech, 2017). The infrastructure also plays an important role in reducing vehicle speeds. A literature review of traffic calming measures, conducted by Vanderschuren and Jobanputra (2009), found evidence that speed humps, speed tables, raised crosswalk, raised intersection, traffic circles, half closures, roadway narrowing and chockers had a positive impact in terms of reducing vehicle speeds.

In terms of the NMT infrastructure, Avenoso and Beckmann (2005) infer that differences in speed and degree of protection between VRUs and other vehicle users, should result in physical separation of footpaths and cycle lanes from the carriage way. Where physical separation is not possible, line markings need to be provided to clearly delimit space provided to VRUs. This intervention will assist in reducing conflicts between VRUs and vehicles, consequently, reducing the chances of pedestrian accidents (Taylor *et al.*, 2003). In developing countries, it has been found that pedestrian crashes mostly occur on high-speed arterials and freeways because pedestrians do not utilise crossing facilities provided (Behrens, 2002). A study by Chu *et al.* (2004) found that this behaviour is a result of the extra walking distance that is required to reach the crossing facility. Therefore, pedestrian crossing facilities located along the pedestrian’s desire line are more likely to be utilised (Slingers, 2012 and Behrens and Makajuma, 2017).

The use of adequate roadway lighting can also reduce the incidence and severity of pedestrian accidents by providing better visibility. Studies in South Africa have found that a large number of fatalities occur at night between 6 pm and 10 pm (Mabunda *et al.*, 2008 and Das, 2014). Studies by Pegrum (1972) and Polus and Katz (1978) have found that increasing intensity of roadway lighting can significantly reduce night-time pedestrian fatalities. Lighting has also been found to be a cost-effective measure by Vanderschuren et al. (2017).

- **Evaluation:** Road safety audits are recommended for both, old and new roads. In the case of new roads, audits ensure that the design adopted is safe for road users i.e. preventing accidents, and in the case of old roads, audits provide a check on the current road design. Intelligent Transport Systems (ITS), such as time-to-collision, that can be calculated using microsimulation, measures the risk of collision along a road stretch (Vanderschuren, 2008). A high time-to-collision reduces the accident risk.

b) Crash

The measures adopted in this column align with VZA whereby the aim is to reduce the risk of a death or a serious injury, as mentioned previously. A measure is recommended for all E's, apart from Education for which no intervention is applicable, and can be described as follows:

- **Enforcement:** As mentioned previously, reduced speed limits have successfully reduced fatalities internationally (Steunenberg and Sinclair, 2014). This is also the case in other countries where Gårder (2004), for instance, found that high vehicle speeds resulted in more crashes. A previous study by Waiz *et al.* (1983) in Zurich found that a speed limit reduction from 60 km/h to 50 km/h resulted in car-pedestrian accidents reducing by 16% and, the number of injured pedestrians and fatalities being cut by 20% and 25%, respectively. McLean *et al.* (1994) reported similar findings where a 5 km/h speed reduction model showed a 32% reduction in fatalities and a 10% reduction in fatal accidents. The authors in the latter study, contribute these findings to the relation of speed reductions and impact speeds, which is in accordance with other studies that suggest high speeds results in the release of high kinetic energy during crashes (Nilsson, 2004 and Aarts and Van Schagen, 2006). In addition to this, high speeds also require vehicles to have a longer stopping distance, which increases stopping times (Wilmot and Khanal, 1999). However, the laws have to be enforced adequately in order to have a positive impact in terms of reducing road fatalities. In the Western Cape Province, South Africa, increased and improved enforcement, alone, has resulted in the reduction of 30% of road fatalities (Vanderschuren and Zuidgeest, 2017).

- **Engineering:** The measures recommended in this cell are mostly adopted in developed countries. Furthermore, only a few studies described the effectiveness of these measures. One measure recommended includes the use of airbags in vehicles, however, airbags have shown low efficiency when seat belts are not used (Barry *et al.*, 1999), hence, there is a need for more research on this area. Fourjah (2003) also found that there is a lack of research on the effectiveness of air bags. In the case of NMT users, high-tech solutions, such as pedestrian airbags in the bonnet of vehicles, have been adopted in European countries (Deutsche Welle, 2006).

- **Evaluation:** After a road crash, fatality sites need to be investigated to determine the cause of the accident by means of accident investigations and/or accident reconstruction techniques. The main investigations include, amongst others, measuring the length of skid marks, determining the vehicle speeds, the road users involved in the crash and the lighting of the surroundings.

c) Post-Crash:

The focus of these measures is to prevent accidents on high-risk hotspots and improve access to crash sites. In high-risk hotspots, road safety audits are undertaken to reduce the crash rates, especially fatal crash rates. Furthermore, by improving access to emergency care facilities, the time taken to provide aid to victims is reduced. Mortality rates can reduce significantly if aid can be provided to victims during the first ‘golden’ hour after the crash (Muckart, 1991 cited by Vanderschuren and McKune, 2015). Measures recommended in this cell can be described as follows:

- **Enforcement:** In high-risk zones, providing adequate enforcement ensures that road users follow the traffic laws. For instance, in South Africa, pedestrian fatalities mostly occur when pedestrians cross high-speed arterials (Behrens, 2002). In this case, after identifying areas with high pedestrian fatalities caused by this poor behaviour, strict enforcement can be used to ensure that pedestrians use overpasses provided and are not exposed to these risks. Furthermore, congestion management is recommended on routes that connect to emergency care facilities. A reduction in congestion would lead to reduced travel time to emergency facilities.

- **Education:** In this case, campaigns are used to train road users on ways to attend to a road crash victim using first aid kits. Information is also provided on the nearest emergency care facilities and ways of accessing these facilities.

- **Engineering:** Based on the cause of accidents, engineering measures are introduced to reduce the number of accidents. This could include introducing adequate lighting in areas with low visibility, or reducing speed limits in residential areas. As a result, the measures recommended in this cell depend on investigations performed on the crash site, i.e. the evaluation measure for the crash stage.

- **Evaluation:** The hotspots, generally, have varying accident risks ranging from high to low. Since LMICs have low road safety budgets, the aim is to prioritise high-risk zones and reduce the accident risks in these zones. Internationally, the risk of zones can be determined by either ranking them in terms of fatalities or using a ‘weighted sum’ approach that considers the number of injuries as well (Elvik, 2007). The former approach is used when both, the fatality numbers and crash numbers are high while the latter approach is used when the fatality numbers are high but crash numbers are low. In this study, zones are ranked in terms of the fatality numbers since the zones meet the criteria of high fatality and high crash values. Furthermore, Elvik (2007) found that, in terms of zone size, various countries limit the zone size to 100m by 100m. This approach is also used in this study when determining the size of zones.

It is the author’s belief that by adopting these interventions, together with the policy and mind-set change recommended previously, LMICs can effectively tackle the current traffic fatalities burden. As mentioned previously, LMIC lack funding in the road safety department, hence, prioritisation of interventions is important. Therefore, before introducing interventions, it is important to determine the most affected road users and the high-risk areas through data analysis, similar to the one performed in this study.

2.3 African Countries

Despite the fact that Africa is the least motorised region of the world (only 2% of world's registered vehicles), the risk of dying, due to a road traffic crash, is 24.1 per 100 000 population (Peden *et al.*, 2013). This is significantly higher than the global average of 17.1 fatalities per 100 000 population or the averages of MIC and HIC (see Figure 2-1). Since all countries in Africa fall under either the low-income or the middle-income category, a similar pattern is seen in terms of road traffic fatalities between these sets of countries. The vulnerable road users in LMIC – pedestrians, cyclists and motorised two- and three-wheelers – make up more than half (52%) of those killed on African roads, with pedestrians, alone, accounting for 37% (WHO, 2015).

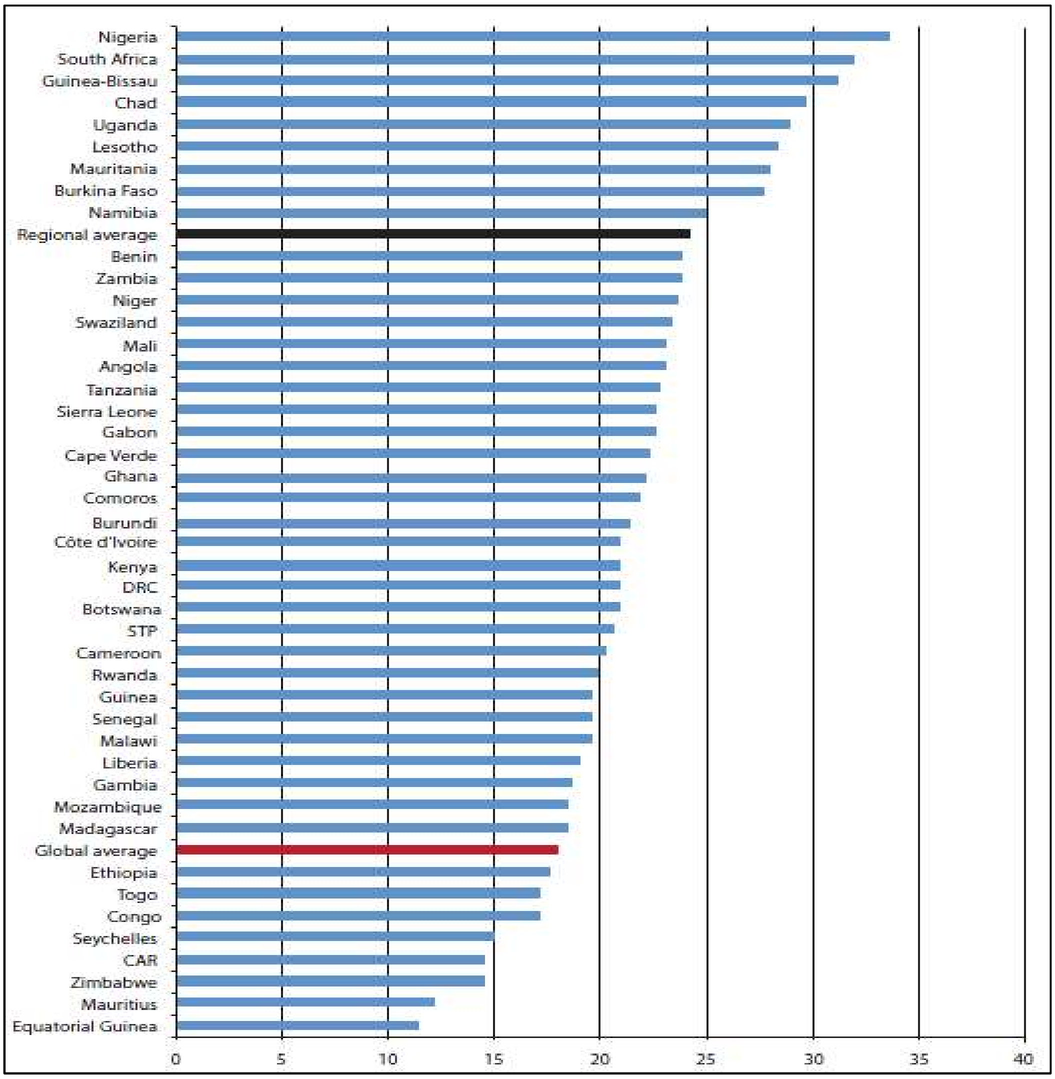

Figure 2-7: Road traffic death rates (per 100 000) in Africa[7] in 2010

Source: Peden *et al.* (2013: 1)

Figure 2-7 shows the mortality rate of each African country together, with values of African- and Global-averages for comparison purposes. As observed, nine countries have averages greater than the regional average, with Nigeria and South Africa having the highest rates at 33.7 and 31.9 per

[7] CAR = Central African Republic; DRC = Democratic Republic of Congo; STP = Sao Tome and Principe.

100 000 population. Democratic Republic of Congo, Ethiopia, Kenya, Tanzania and Uganda, in addition to these two countries, make up 64% of all road traffic fatalities in the region (Peden *et al.*, 2013). Furthermore, 36 out of the 42 countries within the region have fatality rates that are higher than the global average of 17.1 per 100 000 population. Among the road users affected in the region, the majority (62%) were people between ages 15 and 44 years, and 3 out of 4 deaths were males.

The vulnerability of road users also varies within countries, depending on the local factors (Nantulya and Reich, 2003). The variation is especially apparent when comparing urban areas to rural areas whereby pedestrians account for up to two-thirds of people injured or killed due to road traffic crashes in urban areas, while in rural areas the majority of victims are passengers on buses or paratransit services (Odero *et al.*, 2003 and Afukaar *et al.*, 2016). Figure 2-8, for instance, compares road fatalities by road user groups in Nairobi and Nyanza regions in Kenya, which fall under the urban and rural category, respectively.

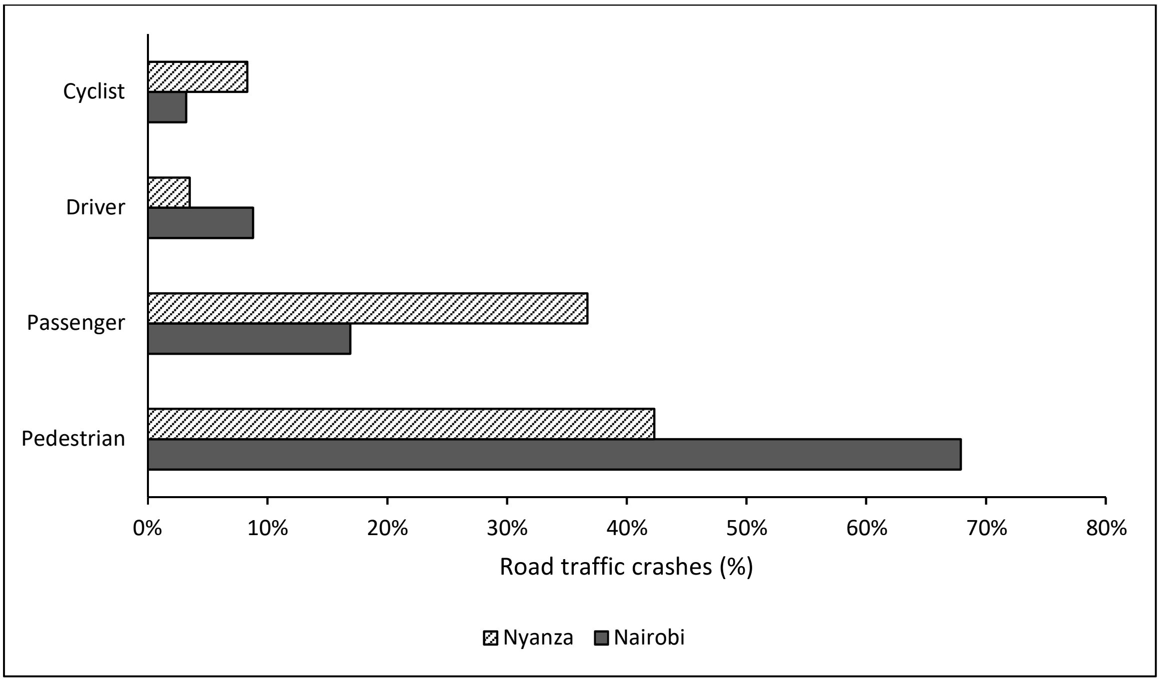

Figure 2-8: Road traffic crashes in rural Nyanza and urban Nairobi (Kenya)
Data Source: Odero (1997, cited by Odero *et al.*, 2003)

As seen in Figure 2-8, Nyanza – the rural region – has a higher number of passenger deaths (36.7%) compared to Nairobi (16.9%) – the urban region. The opposite is true in the case of pedestrians where Nyanza has 42.3% of pedestrian deaths compared to 67.9% in Nairobi. Overall, these two road user group – passengers and pedestrians – were the most vulnerable group in Kenya, making up 80% of road traffic fatalities (Odero *et al.*, 2003). A similar pattern is observed in Ghana, where 66.8% of pedestrian fatalities occurred in urban areas (Afukaar *et al.*, 2016). Pedestrians were also the most affected group in Ghana, comprising of 46.2% of overall road fatalities, followed by riders in passenger-ferrying buses, minibuses and trucks.

The cities within the African countries also vary in terms of the fatality rate, based on the city considered. Figure 2-9 shows the fatality rate in certain African cities, comparing them to African and Global averages, and fatality rates in cities located in HIC, such as Sydney, Toronto and San Francisco. Maputo and Bloemfontein are seen to have the highest fatality rates at 51 and 50 per 100 000 population. This is significantly higher than the averages of the countries where these cities are located i.e. Mozambique (18.5) and South Africa (31.9), respectively. Compared to the African average (24), all cities except Nairobi (23), are seen to have a higher fatality rate.

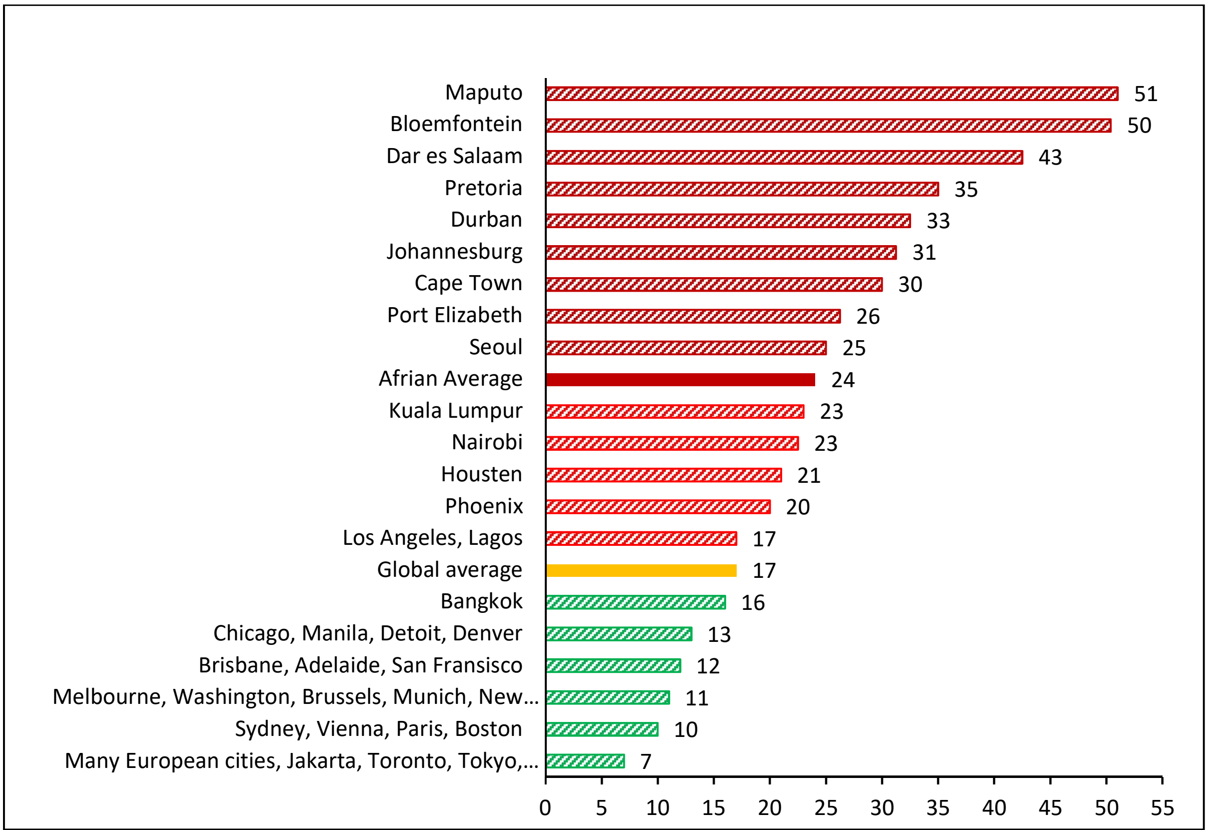

Figure 2-9: Fatality rates of various cities.

Source: Vanderschuren and Zuidgeest (2017)

From the nine African cities analysed by Vanderschuren and Zuidgeest (2017), road vulnerability was analysed for car users, motorcyclists, cyclists and pedestrians in Dar es Salaam, Nairobi and Cape Town. The results showed similar patterns to Kenya and Ghana, discussed previously in this section, whereby pedestrians, cyclists and motorcyclists made up the largest portion of fatalities – between 66% and 88% of road fatalities. Pedestrians make up the most affected group in these cities, i.e. 67 % in Dar-es-salaam, between 59% to 65% (depending on sources) in Nairobi and 57% in Cape Town.

The literature discussed clearly infers that vulnerable road user groups, especially pedestrians, are the most affected group in African cities and countries. Considering the fact that walking is the dominant mode in African cities – 80% of journeys made on foot in some cities (Watson, 2015) – it is bewildering that pedestrians are not provided with adequate infrastructure (Vanderschuren *et al.*, 2017). For instance, in the case of Nairobi, it was found that 95% of roads assessed had high pedestrian flows, but only 20% of these roads had pedestrian footpaths (iRAP, 2009). The legacy of colonialism has obviously affected the planning of these countries with governments still expanding road networks and prioritising motorisation. Due to inadequate NMT planning, it can be inferred that African countries will continue to struggle with high rates of pedestrian fatalities, poor quality NMT environments and increasing dependence on private car use.

There is also a lack of adequate public transport in African countries, with the majority of the population relying on informal transport to fill the gap (Nantulya and Reich, 2003). Within the realm of transport modes, these paratransit services fall between the private automobile mode and the conventional public transport system. These vehicles tend to have 'colloquial' names, for instance *Matatus* in Kenya, *Dala Dala* in Tanzania, the *Molue* (moving morgue) in Nigeria and the taxis of Uganda and South Africa (Kumar and Barrett, 2008). Even though these modes have positive attributes, such as low fares for poor people, they also predispose passengers to high risk of injuries and are accountable for the high passenger deaths. The drivers work long hours during the day to earn a small profit, which results in driver fatigue, sleep deprivation, overloading, reckless driving and high vehicles speeds (Nantulya and Reich, 2003; Odero *et al.*, 2003 and Afukaar *et al.*, 2016).

In addition to this, lack of knowledge by pedestrians on road safety is also seen to be a contributing factor to the high fatalities. A study conducted by Mutto *et al.* (2002) in Kampala (Uganda) showed that, even though 77.9% of pedestrians were worried about their safety, only 6.9% thought an overpass was an appropriate means to avoid traffic accidents. Additionally, walking long distances to access overpasses and other pedestrian crossing facilities is also a contributing factor in the low usage of these facilities (Chu *et al.*, 2004). This has resulted in pedestrians crossing high-speed roads at grade (also known as jaywalking), which increases the risk of dying due to a road crash (Vanderschuren and Zuidgeest, 2017). The growing number of private vehicles also poses a high risk to the vulnerable road users, since the majority of these vehicles do not have roadworthiness certificates (Nantulya and Reich, 2002). Additional factors that contribute to the high number of fatalities in LMIC (discussed in subsection 2.1.2) are poor enforcement of traffic safety regulations, inadequacy of public health infrastructure and poor access to health service.

2.4 South Africa

As mentioned previously, South Africa (RSA) has the second highest fatality rate in Africa at 31.7 fatalities per 100 000 population. Based on the Road Traffic Management Corporation's (RTMC) 2005-2015 reports, Vanderschuren *et al.* (forthcoming) analysed variations in annual fatalities among nine South African provinces[8] (see Figure 2-10). The analysis found that, on average, fatalities in RSA have reduced since 2005. However, after reaching its lowest point in 2013, the annual fatalities have increased for the years 2014 and 2015. Four of the nine provinces – GA, KZN, WC and NW, achieved

[8] Eastern Cape (EC), Gauteng (GA), Free State (FS), Limpopo (LI), Mpumalanga(MP), Northern Cape (NC), North West (NW), Western Cape (WC) and KwaZulu-Natal (KZN)

greater fatality reductions than South Africa and the other five provinces. For the 11 years analysed, the largest variation is observed in FS with the province reducing its annual fatalities from 1 012 in 2005 to 541 in 2013, before increasing to 938 fatalities per annum in 2014 and 2015.

In 2015, South Africa had a total of 12 944 fatalities across all provinces (RTMC, 2015). According to the Department of Transport (2016), the estimated economic burden of road fatalities and injuries is between ZAR 334 billion and ZAR 556 billion. Parkinson *et al.* (2014) found that average hospital care provided to a pedestrian involved in a Road Traffic Crash (RTC) cost US $6 789 (approximately ZAR 716 000 in 2014) with the average cost being higher for a car occupant at US $7 129 (approximately ZAR 751 000 in 2014). The figures suggest that, not only do road fatalities place a significant financial burden on the country, but also to individuals involved in crashes.

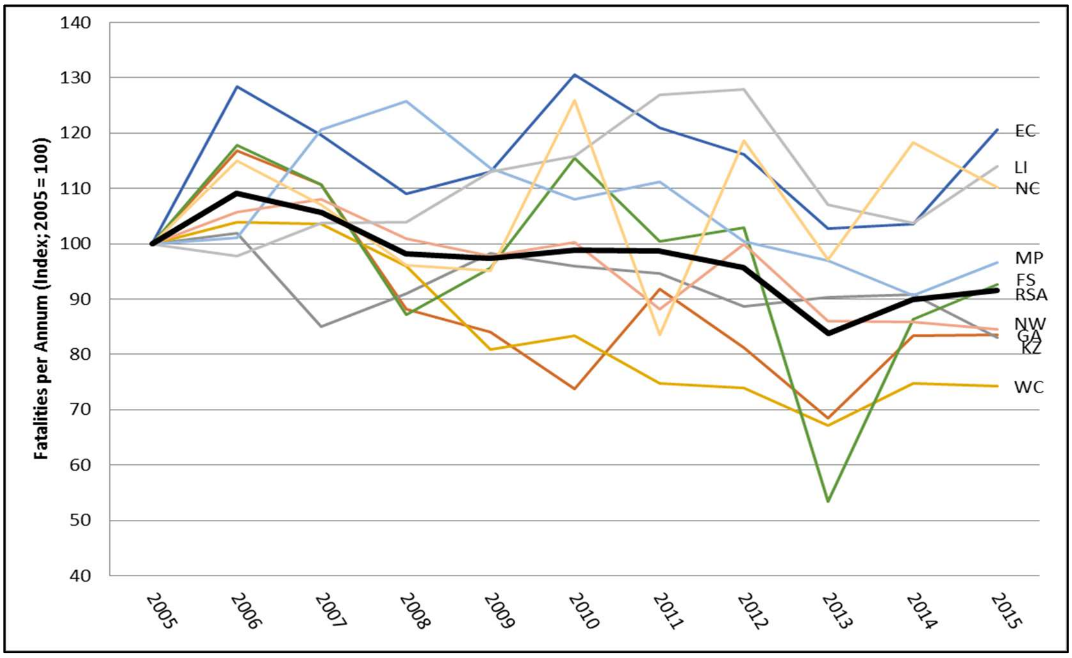

Figure 2-10: Road Fatalities per annum per province (Index: 2005=100)

Source: Vanderschuren et al. (forthcoming)

Similar to the African and other developing countries, pedestrians are the most affected group making up 37.6% of road fatalities in South Africa, followed by car passengers at 32% and drivers at 27% (RTMC, 2015). Mabunda *et al.*, (2008) analysed pedestrian fatalities in four South African cities – Cape Town, Durban, Johannesburg and Pretoria, and found that the ratio for female to male pedestrian deaths was 1:3.3. The analysis also showed that in over half of the cases (58%), tests regarding alcohol abuse were positive. While analysing ethanol related road deaths among users, du Plessis *et al.* (2016) found that drivers had the highest proportion of alcohol in their blood levels, followed by pedestrians and motorcyclists.

However, alcohol abuse is not the only contributing factor to the high pedestrian fatalities. Pedestrians crossing the road, without using crossing facilities, account for 36% of the factors contributing to all fatal crashes in South Africa (Behrens, 2002). In a later study, Behrens (2005) noted that the main reason for this is the design of South African roadways that are based on the ‘hierarchy’ model[9]. The model assumes that people would use private vehicles for trips longer than 10 minutes. However, in South Africa, low-income households that do not have access to cars, are walking longer than 10 minutes (sometimes more than 60 mins) daily. This requires them to cross high-speed arterials, consequently, increasing the likelihood of fatal crashes (Behrens, 2005). Furthermore, studies have found that a large number of pedestrian fatalities occur at night between 6 pm and 10 pm (Mabunda *et al.*, 2008 and Das, 2014). As mentioned previously, these findings emphasise the fact that inadequate lighting can compromise the visibility of pedestrians.

Jungu-Omara and Vanderschuren (2006) reported on vehicles involved in crashes and the accident risk per registered vehicles (see Table 2-4). The study found that most crashes involved sedans/station wagons, however, the risk for this vehicle type is low. Alternatively, Mini Bus Taxis (MBTs) have the highest risk, even though they are involved in 6.5% of crashes. The likelihood of a vehicle being involved in an accident is also influenced by vehicle kilometres travelled by that vehicle type, which influences its density on the road (Vanderschuren and Zuidgeest, 2017). Data on vehicle kilometres travelled might also change the findings in Table 2-4, especially in the case of MBTs, who travel long distances and undertake several trips in one day. However, since data on vehicle kilometres is not recorded in Cape Town, the authors were not able to analyse the data using this information.

Table 2-4: Types and Number of Registered Vehicles Involved in Crashes (2001)

Vehicle type	No. of vehicles involved in accidents	%	No. of registered vehicles	Risk per registered vehicle type
Sedan/ station wagon	85 825	66.0	551 892	0.16
Light delivery vehicle	18 227	14.0	147 306	0.12
Combi/ Minibus Taxi	8 428	6.5	10 254	0.82
GVM >3500 kg	5 274	4.1	18 090	0.29
Motorbike	3 073	2.4	19 717	0.16
Bus	1 394	1.1	5 202	0.27
Articulated trucks	1 212	0.9	2 601	0.47
Other	1 361	1.0	14 515	0.09
Unknown	5 254	4.0	3 240	1.62
Total	130 048	100.0	772 817	

Source: Adapted by Jungu-Omara and Vanderschuren (2006) from Cape Town Metropolitan Council data (www.capetown.gov.za), 2003

The RTMC (2015) notes that three factors contribute to the occurrence of high levels of fatal crashes in the country: human factors, road factors and vehicle factors. Human factors are seen to contribute the highest number of crashes at 79.6% followed by road factors at 12.7% and vehicle factors at 7.8%. Under the human factors category, pedestrian jaywalking and high vehicle speeds were observed to be

[9] The model demarcated South African ‘neighbourhoods’ with high-speed arterials. It was assumed that amenities provided within the neighbourhood would satisfy the daily needs of the local people and would be accessible by 10 minutes of walking. Within the neighbourhood, the local roads and cul-de-sacs were narrowed down to reduce speed and induce a traffic calming effect (Behrens, 2005).

the highest contributors at 52.5% and 11.6%, respectively. In the case of road factors, sharp bends (22%) and poor visibility (16.5%) were the two highest contributors. Lastly, tyres bursting prior to crashes contributed to 71.7% of fatal crashes under vehicle factors, followed by faulty brakes (15.9%).

Overall, the studies reviewed in this section have found that pedestrians in South Africa are the most affected road user group. These findings suggest that South Africa has similar problems, with respect to pedestrian safety, as other developing countries reviewed in the previous sections (see, for instance, Naci *et al.*, 2009; Vanderschuren and Zuidgeest, 2017 and WHO, 2015). It has also been found that alcohol consumption, inadequate lighting, high-speed on arterials and jaywalking have been the main contributors to the high number of pedestrian fatalities. However, none of the studies have unpacked road fatalities at a more disaggregated level than the city. Therefore, this study aims to fill this gap in the literature by identifying the local factors, such as household income and consequently mode usage, that influence road fatalities in the case of Cape Town.

2.5 Summary of Chapter

Globally, RTIs are the ninth leading cause of death and the leading cause of death among young bread earners aged 15-29 (WHO, 2015). However, the risk of dying is not equal for all countries with average fatality rates in LMIC being more than double the average fatality in HIC. A variation is also observed in terms of the road users effected in the two types of countries, with pedestrians constituting the majority of fatalities (38%) in LMIC and car users constituting the majority of fatalities in HIC (63%) (Naci et al., 2009, Nantulya et al., 2003, Mohan, 2002 and WHO, 2015). Naci *et al.* (2009) states that it is important to determine this variation especially in the case of LMIC where road safety budgets are generally low and interventions need to be prioritised.

In recent years, HIC have adopted a VZA that aims to reduce the number of fatal accidents and major injuries from road crashes. This approach has led to the development of best road safety practices in both LMIC and HIC. A review of these practices was conducted in this study in order to provide an overview of interventions that may reduce the high fatality rates in LMIC (see Table 2-3). The most important of these interventions include enforcing traffic laws, correcting road user behaviour through education, providing adequate infrastructure for vulnerable road users, and analysing high-risk areas in order to deduce the localised problem (Vanderschuren and Zuidgeest, 2017).

African countries, as LMIC, show a similar pattern with pedestrians accounting for majority of the fatalities (37%) (Peden *et al.*, 2013). The risk of dying due to a RTC is the highest in Nigeria and South Africa with fatality rates of 33.7 and 31.9 per 100 000 population, respectively. In the case of the latter, pedestrians constitute 37.6% of road fatalities followed by passengers (32%) and drivers (27%) (RTMC, 2015). However, vulnerability of road users varies within a country depending on the influence of local factors (Nantulya and Reich, 2003). Odero (1997, cited by Odero *et al.*, 2003) confirmed this when comparing urban Nairobi to rural Nyanza (in Kenya). Consequently, there is a need of analysing vulnerability of road users at a more disaggregated level before introducing interventions.

3. METHODOLOGY

3.1 Introduction

This Chapter starts by discussing the sequence followed in this study using a flow chart. This is followed by a section on the mathematical approach that depicts the equations used in this study to convert absolute fatality values into various variables. Lastly, the reasons for choosing Cape Town, as a case study, for this research are provided with a brief description on the Cape Town population.

3.2 Flow Chart

This research followed the sequence showed in Figure 3-1:

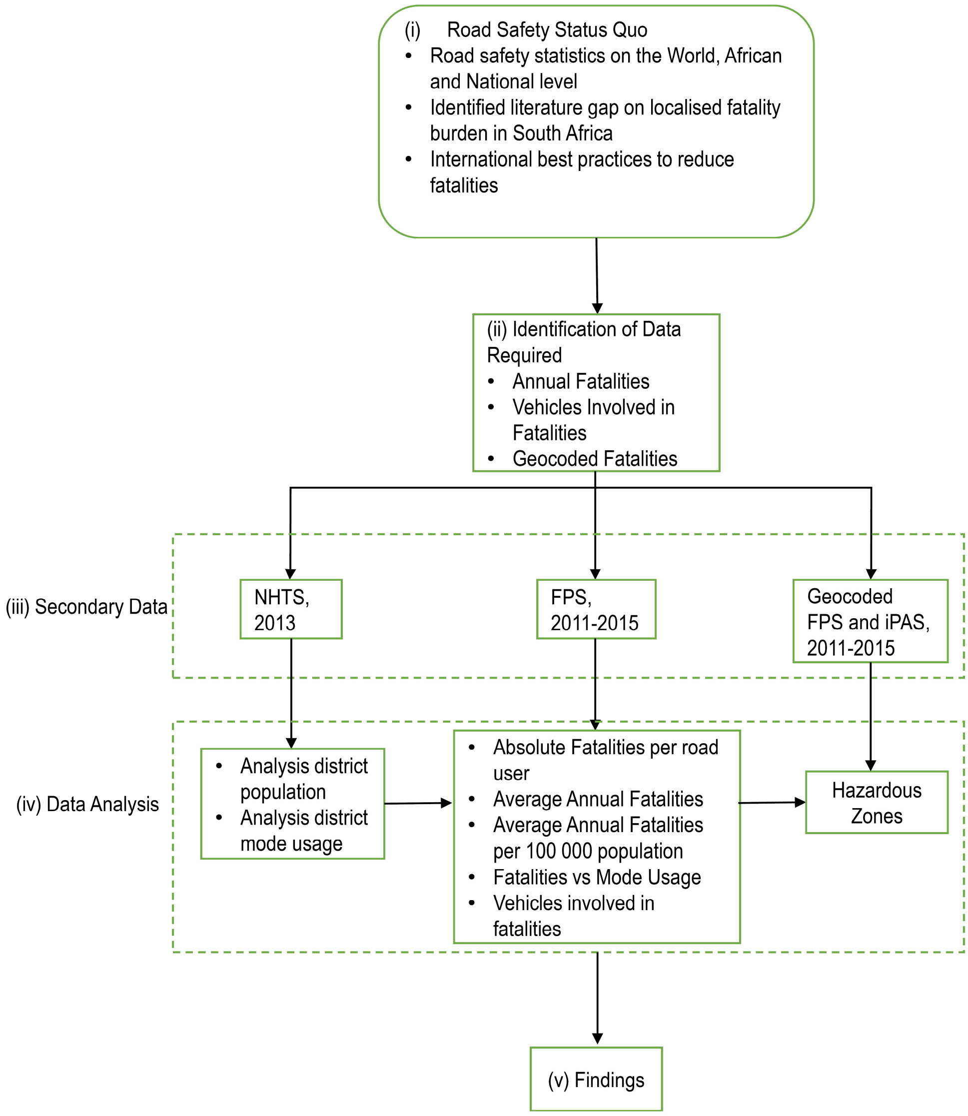

Figure 3-1: Flow chart of methodology

In the flow diagram shown in Figure 3-1, the key research steps are indicated, together with the stage of the research where the process was completed. The arrows indicate how the products of each step provided inputs for the next research step. For each process undertaken, a description, together with the main assumptions and/or limitations for that step are provided below. A detailed description is also provided on the analysis step of the research.

(i) **Road Safety Status Quo**

The literature inferred that LMIC, that account for 82% of the population, bear a higher burden of fatalities than HIC, despite the fact that they account for only 54% of the world's registered vehicles (WHO, 2015). However, not all road users are affected equally with pedestrians, cyclists and motorcyclists accounting for 52% of road fatalities. A similar pattern is observed in African countries with pedestrians accounting for 37% of road fatalities (Peden *et al.*, 2013).

However, the vulnerability of road users is not equal across all African countries with local factors within the country affecting percentage fatalities as well. In the literature, for instance, a comparison of Nyanza (a rural region) and Nairobi (an urban area) in Kenya showed that Nairobi had a significantly higher percentage of pedestrian deaths than Nyanza (Odero, 1997 cited by Odero *et al.*, 2003). In the case of South African cities, studies also showed that pedestrians were the most affected group (RTMC, 2015 and Vanderschuren and Zuidgeest, 2017). None of the studies conducted in South Africa, though, unpacked road safety at a more disaggregate level than the cities. This brings about the notion that the local factors that had an impact on fatalities in Nyanza and Nairobi might also affect fatalities at a disaggregate level in South African cities. It is important that these factors are determined, since a limited road safety budget is provided to developing countries and, therefore, the allocation of resources have to be carefully managed so that a reduction in fatalities can be achieved (Bishai *et al.*, 2003).

The literature on road safety interventions[10] was also reviewed, in order to identify and extract the best practices that have successfully reduced fatality rates. The interventions prescribed, consequently, included but are not limited to: speed reduction, pedestrian friendly infrastructure, helmets, seat belts, air bags and license suspension law.

(ii) Identification of Data Required:

It was deduced that fatalities data at a disaggregated level – in this case, at an analysis district level – would be required to determine the localised burden of road fatalities in Cape Town. In order to determine the road safety burden on both, motorised and non-motorised road users, the data would also have to provide information on five road user groups – cyclists, motorcyclists, drivers, passengers and pedestrians. Consequently, four types of data were identified for a comprehensive analysis. First, the population and mode usage of the various districts in Cape Town would be essential for demographic

[10] See, for instance, Vanderschuren and Zuidgeest, 2017; Fourjah, 2003; Waiz *et al.*, 1983; Vanderschuren *et al.*, 2017; Behrens and Makajuma, 2017; Thompson *et al.*, 1999; Kulanthayan *et al.*, 2004 and Vanderschuren and McKune, 2015.

information. Second, annual fatalities over a long period would be required to examine the trend and averages. Lastly, the geographical location of the fatalities will be required to determine the hazardous zones of the city.

(iii) Secondary Data:

In order to obtain the four types of data described in (ii), the following three sources were identified:

- National Household Travel Survey (NHTS)

This dataset provided information on Cape Town's population and mode usage pattern.

- Forensic Pathology Services (FPS)

The FPS is mandated by the Western Cape province to investigate all unnatural deaths. Hence, data derived from this, provided information on annual fatalities for the five road user groups. In terms of vehicles involved in fatalities, iPAS data would provide a better alternative than FPS since the former provides a better record of fatality conditions. However, access to the iPAS annual fatality data was not available, hence, the analysis was limited to FPS data alone.

- the Provincial Accident System (iPAS)

In terms of geocoded data, access was available to iPAS data for the years 2011-2015 and FPS data for 2015 alone. Similar to data regarding vehicles involved in fatalities, iPAS provides better information than FPS on fatality conditions when analysing geocoded data. Hence, the geocoded data analysis involved both datasets for comparison purposes.

(iv) Analysis:

The analysis performed using each dataset described in (iii) can be explained as follows:

- National Household Travel Survey (2013)

The household travel survey in Cape Town included 8 072 datasets categorised into 18 Traffic Analysis Zones (TAZs). Using the 'Pivot table' function in Microsoft Excel, the population of each TAZ, defined as an analysis district in this study, was determined. In the NHTS survey, the Mitchells Plain TAZ contained the Gugulethu area. However, when analysing the fatalities data, Gugulethu alone showed high fatalities, hence, a separate analysis was performed for the area. A population ratio from the Census (2011) data allowed for a separation of the 2013 NHTS population data. According to the Census data, the population of Gugulethu and Mitchells Plain in 2011 was 98 468 and 310 485, respectively, which results in a ratio of 0.24:0.76 (Gugulethu: Mitchells Plain).

The mode usage in each district was determined using the question related to "mode of travel used in the last seven days (Q2.5 of NHTS METADATA)". For the question, the respondent chose from a set of 21 modes. A list of these modes is provided in the Appendix section. The analysis did not include the Gautrain, since it is not available in Cape Town. Similar to the previous analysis, pivot tables were used to determine the frequency of each mode in each district. Following this, the population that used each mode, at least once in the last seven days, was summed in order to determine the total number of persons that use each of the 21 modes.

The last step of the mode usage analysis (and the NHTS analysis), aggregated the 20 modes to nine modes i.e. Train, Bus, Metered Taxi, Minibus Taxi, Car Passenger, Car, Cycle, Walk and Other. In order to perform this step, the population that used certain modes were condensed using the 'SUM' function in MS Excel. Table 3-1 shows the modes aggregated to comprise the nine modes.

Table 3-1: 2013 NHTS mode used to aggregated to nine modes

Aggregated Mode	Previous Modes
Train	Train, Long-distance train
Bus	Bus, BRT
Metered Taxi	Metered Taxi, Sedan Taxi, Bakkie Taxi
Minibus Taxi	Minibus Taxi, Long distance Minibus Taxi
Car Passenger	Car Passenger, Truck Passenger
Car	Car Driver, Truck Driver
Cycle	Cycle
Walk	Walk
Other	Company Vehicle, Motorcycle, Animal Drawn Transport, Boat and Aircraft

- Forensic Pathology Services (2011-2015)

The analysis using this data involved extracting information on absolute fatalities of the five road user groups from 2009 to 2015, recorded in each South African Police Service (SAPS) across the Western Cape. The first step of the analysis was limiting the study to the City of Cape Town for five years i.e. 2011 to 2015, since initial analysis with 2010 data showed that 2010 World Cup might have affected the fatalities recorded.

The second step involved the manual allocation of each SAPS to the 19 districts of the City. A Google search determined the location of each SAPS. By crosschecking the position of the police service with the analysis districts map (shown in Figure 1-2 in Chapter 1), the allocation was complete. In the case of one analysis district, Oostenberg, no SAPS office could be allocated in the area, hence, no fatalities are recorded throughout this study for this district. This anomaly is obviously caused by gaps in the available fatalities data. As a result, findings in this study are underrepresented and do not account for the Oostenberg population that constitutes of 3.7% of the Cape Town population (NHTS, 2013). In the third step, the 'SUMIF' function[11] in MS Excel combined the fatalities for each district for each road user group. The final step involved adding up all fatalities from 2011 to 2015 in order to obtain the total number of fatalities during that period for each district. Analysis of 'mode involved in the fatality of each road user group' involved the same approach with additional analysis on the risk involved per registered vehicle, similar to the one performed by Jungu-Omara and Vanderschuren (2006) (see Table 2-4).

[11] The SUMIF function in MS Excel allows the users to sum the values in a different cell provided a criteria is met using a value in a different cell. In this case, for instance, if 10 SAPS corresponded to Atlantis, the fatality values of all 10 SAPS would be summed to provide a value for the fatalities in Atlantis.

Following the analysis described above, the total fatalities were converted into two variables: AAF and AAF per 100 000 population. The results of this analysis were then shown using Excel charts and the Cape Town base map, obtained from 2013 NHTS files, in ArcGIS[12]. A minor adjustment was made to the shape file obtained from the NHTS data to show the area covered by Gugulethu. The same map displayed results from the analysis of vehicles involved in road fatalities.

In the case of analysis involving "Fatalities per road user group vs Mode usage", the calculations and graphs were prepared using MS Excel only. Firstly, the mode usage data was aggregated to the five road users in order to compare the two variables. Secondly, the percentage mode usage and percentage fatalities for each road user group was calculated. Lastly, the difference between percentage fatalities and percentage mode usage was determined and shown using MS Excel graphs.

- Geocoded Data

As mentioned in (iii), two datasets were used for geocoded data - iPAS, 2011-2015 and FPS, 2015. Each dataset in FPS provided information on the road user group affected, the speed limit, time of day and the number of fatalities that occurred during the accident. In the iPAS data, the same information was provided, in addition to the number of persons that were injured in each location. The analysis using these datasets identified the high-risk hotspots in the city.

As mentioned in section 2.1.4, in this study, the zones were ranked based on the number of fatalities because both the fatality numbers and the crash numbers are high for the Cape Town zones. This is found to be an acceptable method internationally when zones meet these two criteria (Elvik, 2007). Furthermore, in terms of zone size, Elvik (2007) found that various countries limit the zone size to 100m by 100m. Therefore, to identify these zones, the City area was divided into rectangular cells of 100m by 100m using the 'Fishnet' tool in ArcGIS. The 'Join' tool in ArcGIS then combined all recorded fatalities and accidents in each rectangular cell. This tool is useful in ArcGIS when combining two shape files. In this case, the coordinates shape file was combined with the fishnet shape file to collate all datasets that were located within each cell in the fishnet. The findings display the fatalities in the top 10 hazardous zones and discuss the conditions that led to a high number of fatalities in the top three zones alone due to the limitation of this study.

(v) Findings:

In this step of the research, the outcomes of the analysis for each dataset are described in detail with particular indication of important results. The literature is also referenced in this section to compare this study's findings to studies reviewed in step (i). This is the case especially with findings from geocoded data where the literature on best practices is referenced for possible interventions

[12] ArcGIS is a geographic information systems software that enables the user to analyse and display information using geographic maps (ESRI, 2004).

3.3 Mathematical Approach

In order to calculate the variables described in the analysis step of the research (see previous section), a set of equations were used. A brief description is provided for each variable below together with the equation used:

a) Average Annual Fatalities (AAF):

This variable was determined for the five road user groups – cyclists, motorcyclists, drivers, passengers and pedestrians using Equation 3.1, which provided the average annual performance of each district over the five years (2011-2015).

$$F_A = \frac{F_T}{5} \tag{3.1}$$

Where:
F_A = AAF
F_T = total fatalities over five years

b) Average Annual Fatalities per 100 000 (AAF per 100 000):

As mentioned previously AAF per 100 000, also known as fatality rates or mortality rates, are a useful indication to determine the risk of dying, due to a road traffic crash (WHO, 2015). Although fatality rates are, generally, used for comparisons at a country level, they are used in this study to determine where the district stands in comparison to the country and other districts. Equation 3.2 was used to calculate this variable.

$$F_M = \frac{F_A}{P_T} \times 100{,}000 \tag{3.2}$$

Where:
F_M = mortality rate or AAF per 100 000 population
F_A = average annual fatalities
P_T = 2013 population of analysis districts

c) Percentage mode used and percentage fatalities:

The percentage mode used was determined using 2013 NHTS population data, as described in the previous section. For cyclists and pedestrians, a difference could be performed easily since the specific mode usage was present. However, for drivers and passengers, certain assumptions had to be made since both were a component of cars, minibus taxis and buses. In the case of drivers, it was assumed that in a metered taxi, a 10-seater minibus taxi and a 20-seater bus, the factor represented by the driver, would be 1/2, 1/10 and 1/20, respectively. Consequently, the factors 1/2, 9/10 and 19/20 represented metered taxi passengers, minibus taxi passengers and bus passengers, respectively. This calculation is shown in Equations 3.3 and 3.4 with the percentage mode usage variable calculated using Equation 3.5.

The percentage fatalities were determined for five years for each road user group, excluding motorcyclists. This variable was calculated using Equation 3.6. In the case of motorcyclists, both fatalities and mode usage showed low values, hence, no reliable analysis was possible. A difference was then calculated between percentage mode usage and percentage fatalities, with a positive difference indicating that the percentage death toll for the road user type is higher when compared to the percentage of the population that prefers that particular mode for their daily trips, and vice versa. A positive difference also indicates that the road users are killed in accidents near to their destinations of travel rather than areas close to their homes.

$$P_D = P_C + 0.5 \times P_{MT} + 0.1 \times P_T + 0.05 \times P_B \tag{3.3}$$

$$P_P = P_C + 0.5 \times P_{MT} + 0.9 \times P_T + 0.95 \times P_B \tag{3.4}$$

$$M_{\%} = \frac{P_M}{P_T} \times 100 \tag{3.5}$$

$$F_{R,\%} = \frac{F_R}{F_T} \times 100 \tag{3.6}$$

Where:
P_D = number of people that drive
P_{MT} = number of people that use metered taxis
P_T = number of people that use minibus taxis
P_B = number of people that use buses
P_P = number of people that ride as passengers
$M_{\%}$ = mode usage in percentage
P_M = population that uses the mode
$F_{R,\%}$ = fatality per road user group in percentage

3.4 Case Study Description and Selection

In the Western Cape, Cape Town constitutes of 69% of the population (NHTS, 2013), making it the most populous city in the Province. In terms of the analysis districts, Atlantis, Blue Downs, Khayelitsha and Mitchells Plain are densely populated with more than 300 000 people (see Figure 3-2). Alternatively, Somerset West is observed to be the least populated analysis district with less than 53 000 people. In terms of fatalities, initial analysis with data available, deduced that fatalities in Cape Town constitute of a little over half of the fatalities that occur in the Western Cape during the analysis period of 2011-2015 (see Figure 3-3). Therefore, any analysis performed in Cape Town would represent majority of the population and majority of the fatalities. Thus, Cape Town was chosen as a case study for this thesis.

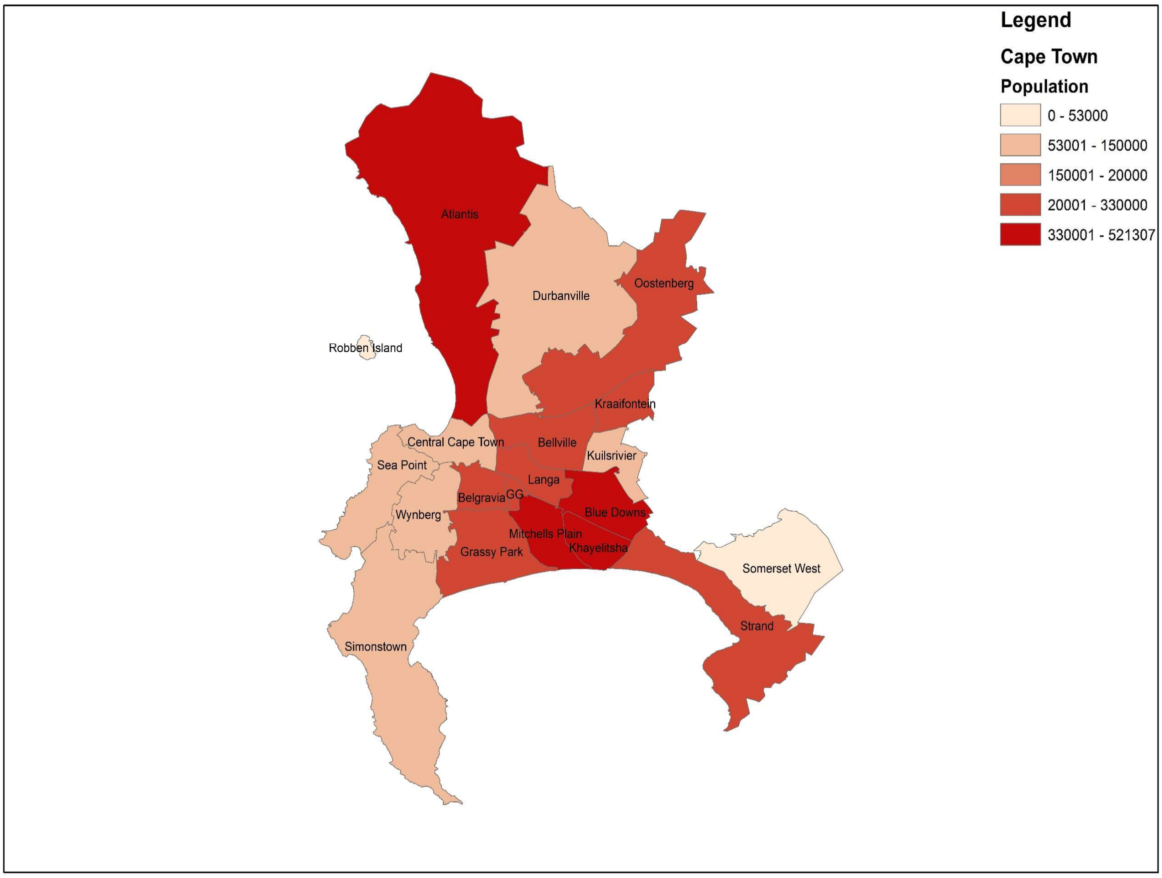

Figure 3-2: Population distribution in Cape Town

Data Source: NHTS, 2013

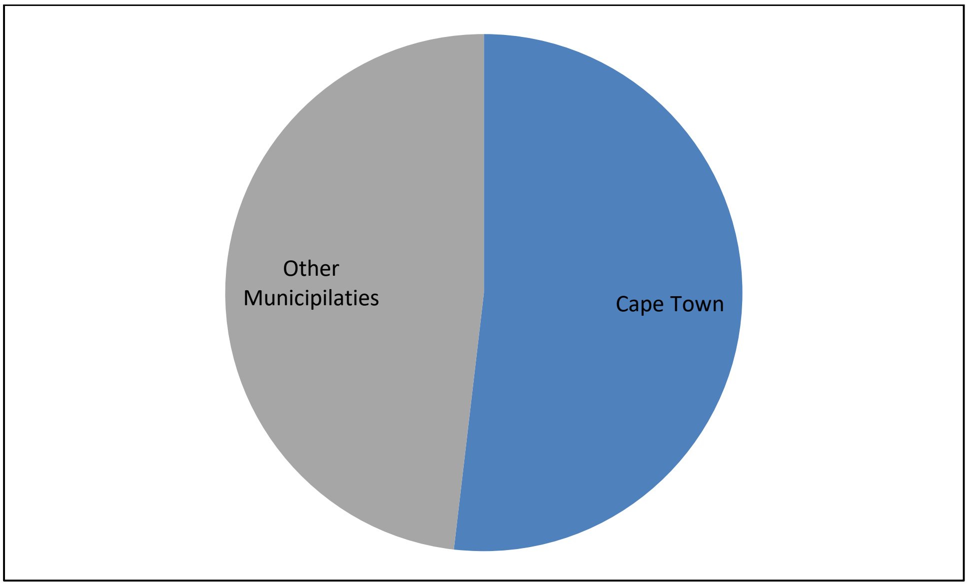

Figure 3-3: Total Fatalities in Cape Town vs Other Municipalities

Data Source: FPS, 2011-2015

The other reason for choosing Cape Town is the significant variation in the local factors that affect the population. Due to the segregated planning of the Apartheid system in South Africa, a large variation still exists in terms of access to facilities and poverty in the cities. Cape Town has similar variations with people living in townships – Khayelitsha, Gugulethu, Langa and Mitchell's Plain – still suffering from the effects of the previous inequitable planning structures. To support this argument, a separate analysis[13] was performed using 2013 NHTS household data to determine the variation in income, mode usage and number owned between the TAZs (defined as analysis districts in this dissertation). The results of the analysis are shown in Table 3-2, 3-3 and 3-4.

The variation in income, as shown in Table 3-2, is quite vast, with majority of the households in townships earning less than ZAR 8 000 per month. Central Cape Town, Kuilsrivier, Sea Point and Wynberg have an almost equal distribution of income between them. In contrast, majority of the households in Durbanville, Simon's Town and Oostenberg earn more than ZAR 25 000 per month. Similarly, in terms of mode usage (see Table 3-3), majority of the households in townships are seen to rely on trains, buses and minibus taxis as their main mode of transport. Private car usage is prominent in Cape Town, Durbanville, Kraaifontein, Kuilrivier, Oostenberg, Bellville, Sea Point, Strand and Wynberg.

Table 3-2: Variation in income per analysis district

Analysis District	<ZAR 3000	ZAR 3000-7999	ZAR 8000-14999	ZAR 15000-25000	>ZAR25000
Belgravia	33%	28%	17%	13%	10%
Blue Downs	34%	38%	17%	5%	5%
Central Cape Town	26%	21%	23%	12%	19%
Durbanville	24%	10%	20%	10%	36%
Grassy Park	19%	21%	26%	14%	20%
Khayelitsha	53%	31%	10%	5%	1%
Kraaifontein	30%	22%	17%	14%	17%
Kuilsrivier	16%	18%	21%	16%	28%
Langa	34%	35%	20%	7%	4%
Mitchells Plain/Gugulethu	40%	37%	12%	8%	3%
Atlantis	26%	24%	20%	14%	16%
Oostenberg	14%	8%	9%	11%	57%
Bellville	19%	31%	23%	13%	14%
Sea Point	25%	19%	18%	14%	25%
Simonstown	25%	11%	20%	12%	32%
Somerset West	48%	0%	12%	21%	19%
Strand	41%	20%	13%	13%	13%
Wynberg	15%	9%	21%	15%	39%

Data Source: NHTS, 2013

[13] In cases where no answer was provided for the questions, the sample was discarded.

Table 3-3: Mode usage per analysis district

Analysis District	Train	Bus	Metered Taxi	Minibus Taxi	Car Passenger	Drivers	Cycle	Walk
Belgravia	14%	14%	0%	12%	25%	28%	1%	1%
Blue Downs	21%	9%	0%	31%	10%	15%	1%	2%
Central Cape Town	14%	5%	2%	15%	18%	41%	0%	2%
Durbanville	17%	1%	0%	1%	14%	62%	0%	0%
Grassy Park	12%	6%	1%	13%	27%	38%	0%	0%
Khayelitsha	27%	31%	0%	21%	2%	11%	0%	1%
Kraaifontein	20%	2%	0%	20%	5%	47%	0%	1%
Kuilsrivier	15%	0%	3%	11%	3%	66%	0%	0%
Langa	12%	5%	0%	59%	3%	14%	1%	1%
Mitchells Plain/ Gugulethu	23%	25%	0%	21%	16%	8%	0%	3%
Atlantis	13%	14%	0%	14%	16%	39%	0%	2%
Oostenberg	13%	1%	0%	1%	6%	77%	0%	0%
Bellville	11%	1%	0%	12%	10%	59%	0%	1%
Sea Point	13%	3%	0%	8%	15%	58%	0%	0%
Simons Town	11%	2%	0%	5%	30%	43%	2%	4%
Somerset West	33%	0%	0%	0%	24%	41%	0%	2%
Strand	15%	0%	1%	15%	3%	54%	0%	2%
Wynberg	11%	1%	0%	4%	27%	54%	1%	0%

Data Source: NHTS, 2013

In terms of car ownership, almost three quarters of the population in townships do not own a car (see Table 3-4). At least half of the households in Central Cape Town, Kraaifontein, Atlantis and Bellville have access to one car. The households in Somerset West also have access to at least one car. As would be expected, the results from these three analysis are linked and dependent on each other. The vast variations in income, mode usage and car ownership within Cape Town strongly suggest that the population in each district is exposed to different road environments. Therefore, the results of this study's analysis of Cape Town will assist in understanding the role of local factors on the fatality burden within the city.

Table 3-4: Number of cars owned per analysis district

Analysis District	0	1	2	3	4 or more
Belgravia	51%	26%	17%	4%	1%
Blue Downs	73%	23%	1%	1%	2%
Central Cape Town	48%	37%	14%	1%	1%
Durbanville	22%	27%	35%	13%	3%
Grassy Park	36%	39%	15%	9%	1%
Khayelitsha	90%	9%	0%	0%	0%
Kraaifontein	50%	19%	28%	2%	2%
Kuilsrivier	33%	21%	36%	9%	1%
Langa	71%	19%	6%	3%	0%
Mitchells Plain/Gugulethu	76%	21%	3%	0%	0%
Atlantis	44%	24%	26%	4%	1%
Oostenberg	12%	28%	43%	11%	6%
Parow/Bellville	42%	31%	22%	4%	0%
Sea Point	28%	31%	31%	7%	2%
Simonstown	27%	23%	36%	11%	3%
Somerset West	0%	50%	42%	8%	0%
Strand	55%	32%	10%	3%	0%
Wynberg	14%	29%	43%	11%	4%

Data Source: NHTS, 2013

3.5 Summary of Chapter

The findings from the literature review confirmed that the road users affected the most within a country may vary depending on the impact of local factors such as mode usage, population and income (Nantulya and Reich, 2003). The differential between urban Nairobi and rural Nyanza confirmed this with Nairobi having significantly higher pedestrian fatalities (Odero, 1997 cited by Odero *et al.*, 2003).

In South African cities, pedestrians also constitute of majority of road fatalities (RTMC, 2015 and Vanderschuren and Zuidgeest, 2015). However, the variation in Nyanza and Nairobi suggests that local factors may also play a role at a more disaggregated level than the South African cities. Therefore, this study aimed to analyse the impact of this variation at an analysis district level for the case of Cape Town, as initial analysis showed that majority of fatalities in Western Cape occurred in this city. Furthermore, the City also shows a significant variation in terms of local factors such income, mode usage and car ownership that impact that population.

The study identified three data sources to conduct this study: NHTS (2013), FPS (2011-2015) and iPAS. (2011-2015). The first dataset, NHTS, provided information on population and mode usage for the analysis districts. The analysis using the second dataset, FPS, extracted information on total fatalities and annual fatalities from 2011-2015 for the five road user groups analysed – drivers, cyclists, motorcyclists, pedestrians and passengers. These absolute numbers were then used to calculate the fatality rates and the percentage difference between fatalities and mode usage using mathematical equations developed (see section 3.3). The FPS data also contained information on vehicles involved in fatalities, which determined the risk per registered vehicle, similar to analysis by Jungu-Omara and Vanderschuren (2006). The last part of the analysis determined the hazardous zones of the city by ranking the zones based on the number of fatalities (Elvik, 2007). The findings show the top 10 zones based on the results with a detailed description on fatality conditions provided for the top three zones in the city. This analysis used both the iPAS and FPS dataset since the former provides a better account of fatality conditions.

4. FINDINGS

4.1 Introduction

This Chapter discusses the main results of the analysis. A comparison between this study's findings and the findings of the existing studies is provided as well, where applicable. In the case of the geocoded data, the literature on road safety best practices is used to recommend interventions that would reduce the fatality burden.

4.2 General

A total of 3 334 fatalities (approximately 667 fatalities/year) were recorded in the City of Cape Town for the years 2011-2015. The City depicts a similar trend to that shown, in general, by South Africa (see Figure 2-10) when analysing that period, during which an initial decrease from 2011 to 2014 was followed by an increase from 2014 to 2015 (see Figure 4-1). The fatalities for the five road user types follow the same trend, except in the case of motorcyclists, where fatalities increased in the first year but continued to decrease thereafter. In the case of cyclists and drivers, a large increase was observed in the final year.

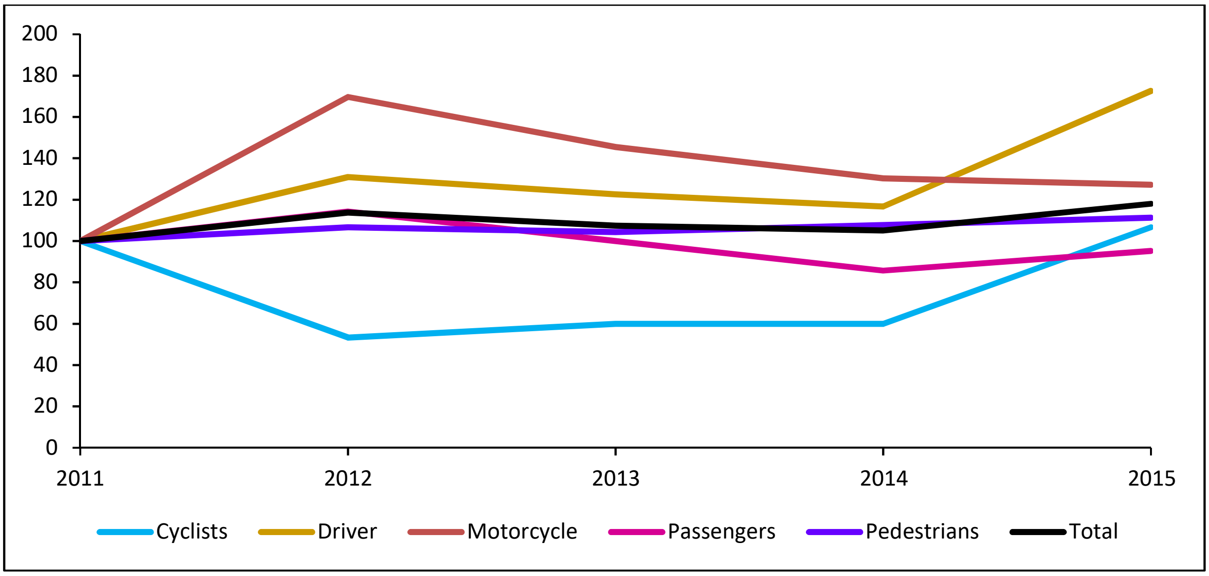

Figure 4-1: Road fatalities per annum per road user group (Index: 2011 = 100)

Data Source: FPS, 2011-2015

Figure 4-2 compares the percentage of total fatalities that each road user type contributes to, in the Western Cape and Cape Town, during the 2011-2015 period. Generally, pedestrians contribute to the largest portion of road fatalities in these areas, 46% in Western Cape and 58% in Cape Town. This finding suggests that Cape Town roads are more dangerous for pedestrians than those in more rural Western Cape. On the other hand, automobile user fatalities, that include both passengers and drivers, were found to be at a higher risk when using Western Cape roads (46% of total road deaths) than on Cape Town roads (33% of total road deaths). This finding can be attributed to the higher speeds on rural roads and the long distance public transport trips, undertaken on the national roads, that causes driver fatigue, sleep deprivation and reckless driving (Nantulya and Reich, 2003; Odero *et al.*, 2003 and Afukaar *et al.*, 2016).

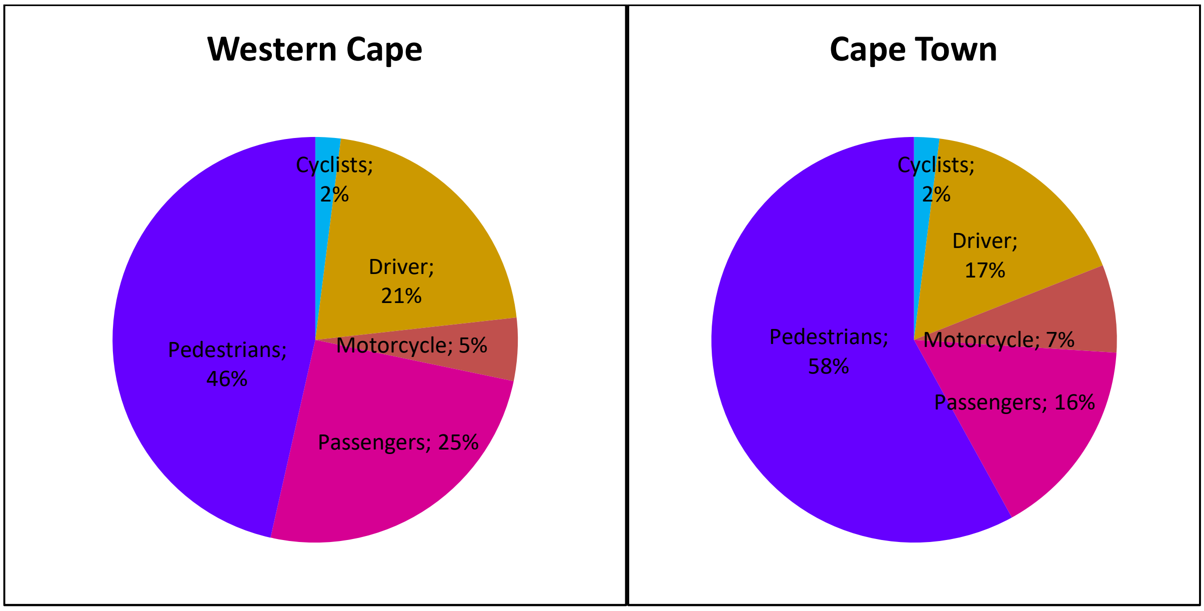

Figure 4-2: Fatalities for different road user groups in the Western Cape and Cape Town

Data Source: FPS, 2011-2015

4.3 Fatalities per Road User Group

Figures 4-3 and 4-4 depict the total number of fatalities from 2011 to 2015 involving cyclists, motorcyclists, drivers, passengers and pedestrians, for each analysis district. Overall, Blue Downs has the highest number of fatalities during the five years, followed by Khayelitsha and Bellville, respectively. These analysis districts, together with Central Cape Town and Mitchells Plain, are seen to have more than 300 fatalities in the five years when considering all road users. In the case of Central Cape Town, the presence of the mortuary in the district may have overrepresented the fatalities data in this district. This is because FPS data collectors assign fatalities to the mortuary location when the actual fatality location is unknown. As mentioned previously in the Methodology Chapter, Oostenberg records zero fatalities because no SAPS office could be allocated to this analysis district.

In terms of specific road user fatalities, pedestrians are the most affected group in all analysis districts, with total fatalities varying from 256 in Khayelitsha (68.6% of total fatalities in that analysis district) to 15 in Sea Point (39.5% of total fatalities in that analysis district). This finding is consistent with findings in South Africa where pedestrians are observed to be the most vulnerable group constituting of 37.6% of fatalities (RTMC, 2015). More than 100 pedestrians were killed due to road traffic crashes in Kraaifontein (119), Bellville (169), Blue Downs (245), Grassy Park (153), Mitchells Plain (228), Central Cape Town (167), Durbanville (106), Gugulethu (117) and Khayelitsha (256), during the five-year research period.

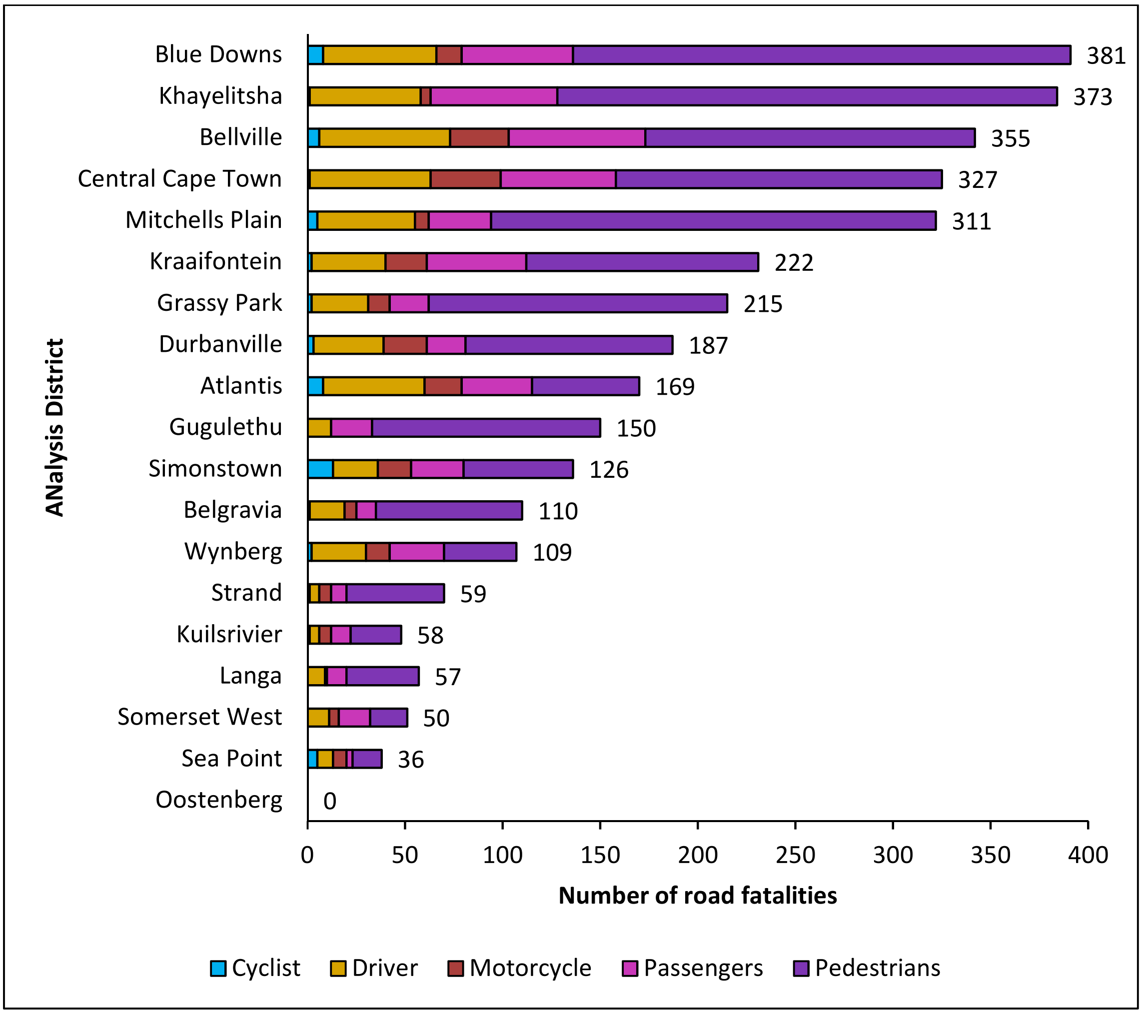

Figure 4-3: Total number of fatalities for each road user group

Data Source: FPS, 2011-2015

Generally, drivers and passengers are the second and third most affected groups, consisting of approximately 17% and 16% of total fatalities, respectively, during the five years. In South Africa, this is not the case with passenger fatalities being higher than driver fatalities (32% vs 27%) (RTMC, 2015). However, the impact on drivers varied depending on the analysis district considered with driver fatalities observed to be higher than passenger fatalities in Central Cape Town, Atlantis, Blue Downs, Belgravia, Grassy Park, Mitchells Plain, Durbanville and Sea Point. Alternatively, passenger fatalities are observed to be higher than driver fatalities in the other 11 districts.

Motorcyclists and cyclists are the fourth and fifth most affected group overall, constituting 7% and 2% of total fatalities, respectively. Motorcyclists are observed to be most affected in Bellville and Central Cape Town, where they constitute approximately 9% and 11% of total fatalities in the district. In certain districts, motorcyclists are affected more than drivers, as observed in Strand (10% vs 9%) and Kuilsrivier (10% vs 9%). In other districts, motorcyclists are affected more than passengers as observed in Durbanville (12% vs 11%) and Sea Point (19% vs 8%). In the case of cyclists, only one district, i.e. Simons Town, is observed to have more than 10 fatalities and is, hence, seen as an area of concern for this particular road user group.

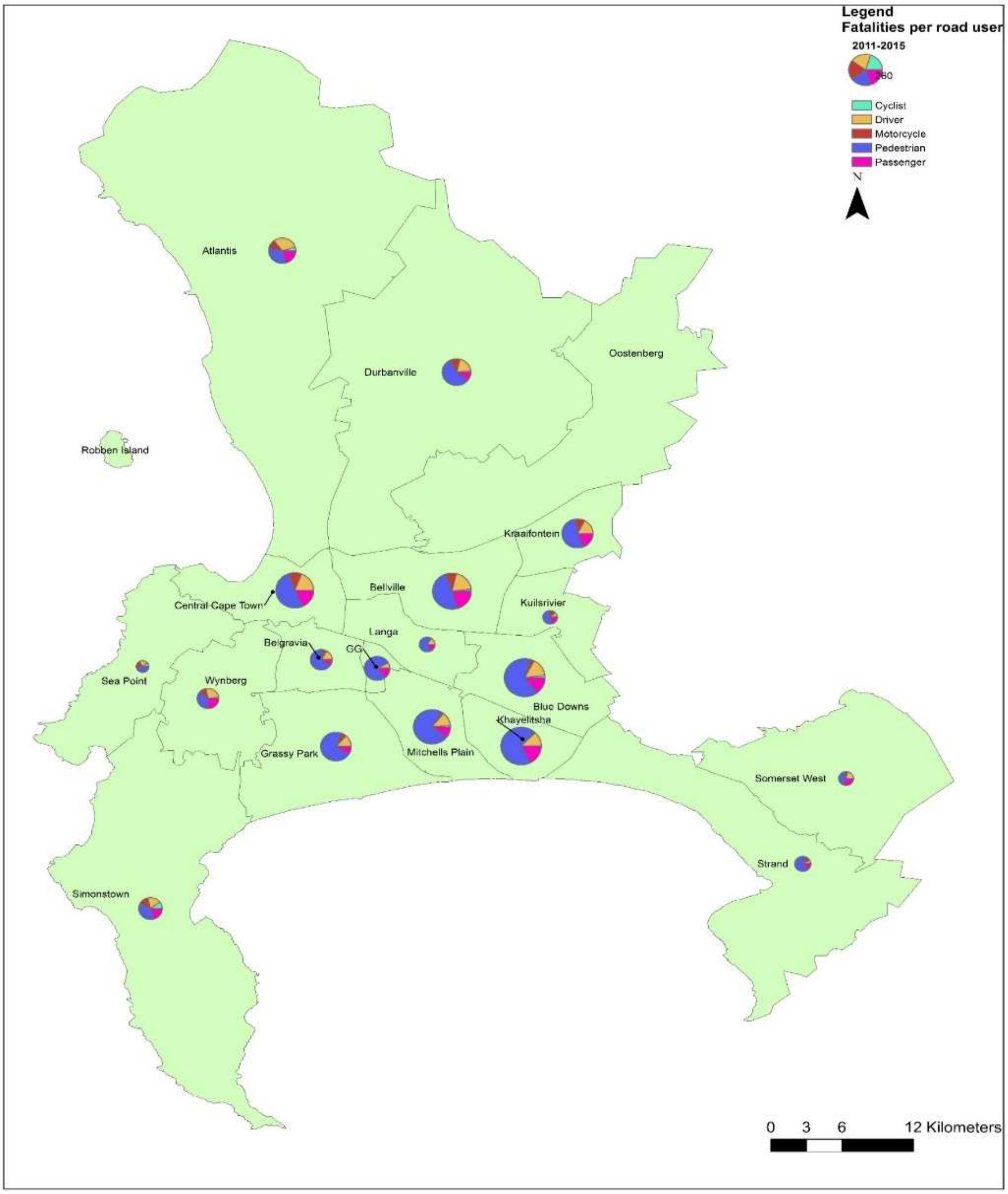

Figure 4-4: Total number of fatalities for each road user group

Data Source: FPS, 2011-2015

4.4 Fatalities per Road User Group vs Mode usage

In section 3.3, household mode usage was described per district. However, for the analysis in this section, population (or individual persons) mode usage was used. The analysis performed was based on the NHTS (2013) data that provided information on mode used by the population per analysis district in the seven days prior to the survey (see Figure 4-5). As would be expected, the population mode usage does not vary significantly from household mode usage, with car usage remaining dominant in high-income areas and public transport usage remaining dominant in low-income areas. However, variation can be observed with regards to 'walking' whereby in the townships – Blue Downs (44%), Mitchells Plain (41%), Khayelitsha (36%), Langa (38%) and Gugulethu (41%) – a large percentage of the population accessed their destination through walking rather than using public transport. No change is observed with regards to high-income areas though, with private car usage remaining dominant in Somerset West (78%) and Durbanville (52%).

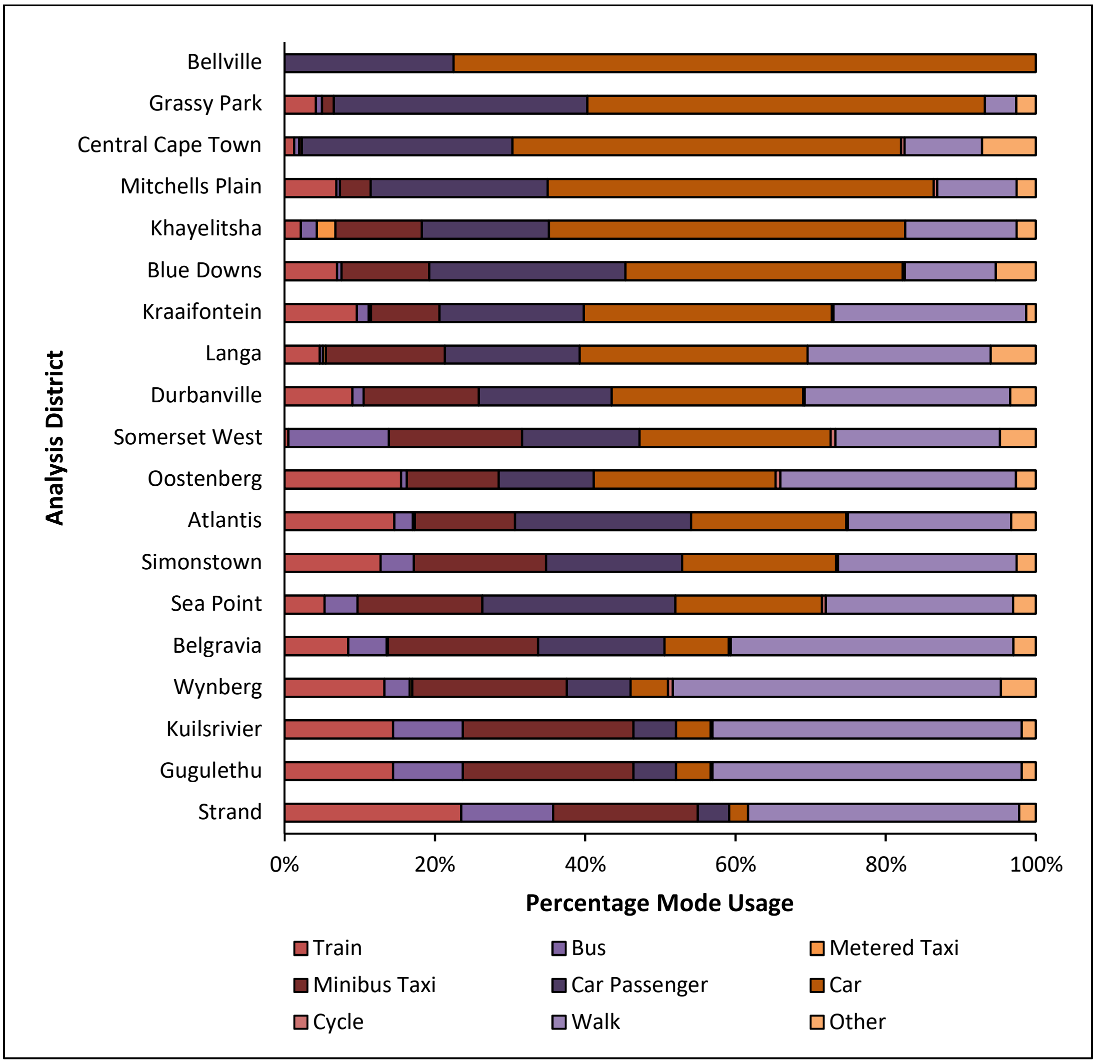

Figure 4-5: Mode distribution in the Cape Town districts

Data Source: NHTS, 2013

Using the mode usage determined in NHTS (2013), the difference between percentage fatalities and percentage mode usage was determined. A positive difference would indicate that the percentage of road user fatalities are higher than the relative percentage of the population that uses the mode in the district. This would also indicate that road users are killed in accidents near to their destination of travel rather than areas close to their homes. The opposite is true for a negative difference. Since, the fatality rates and mode usage for motorcyclists was very low (as seen in Figure 4-3 and 4-4), this analysis was limited to four road user groups- drivers, passengers, pedestrians and cyclists. The results of the analysis for each road user group are shown in Figure 4-6.

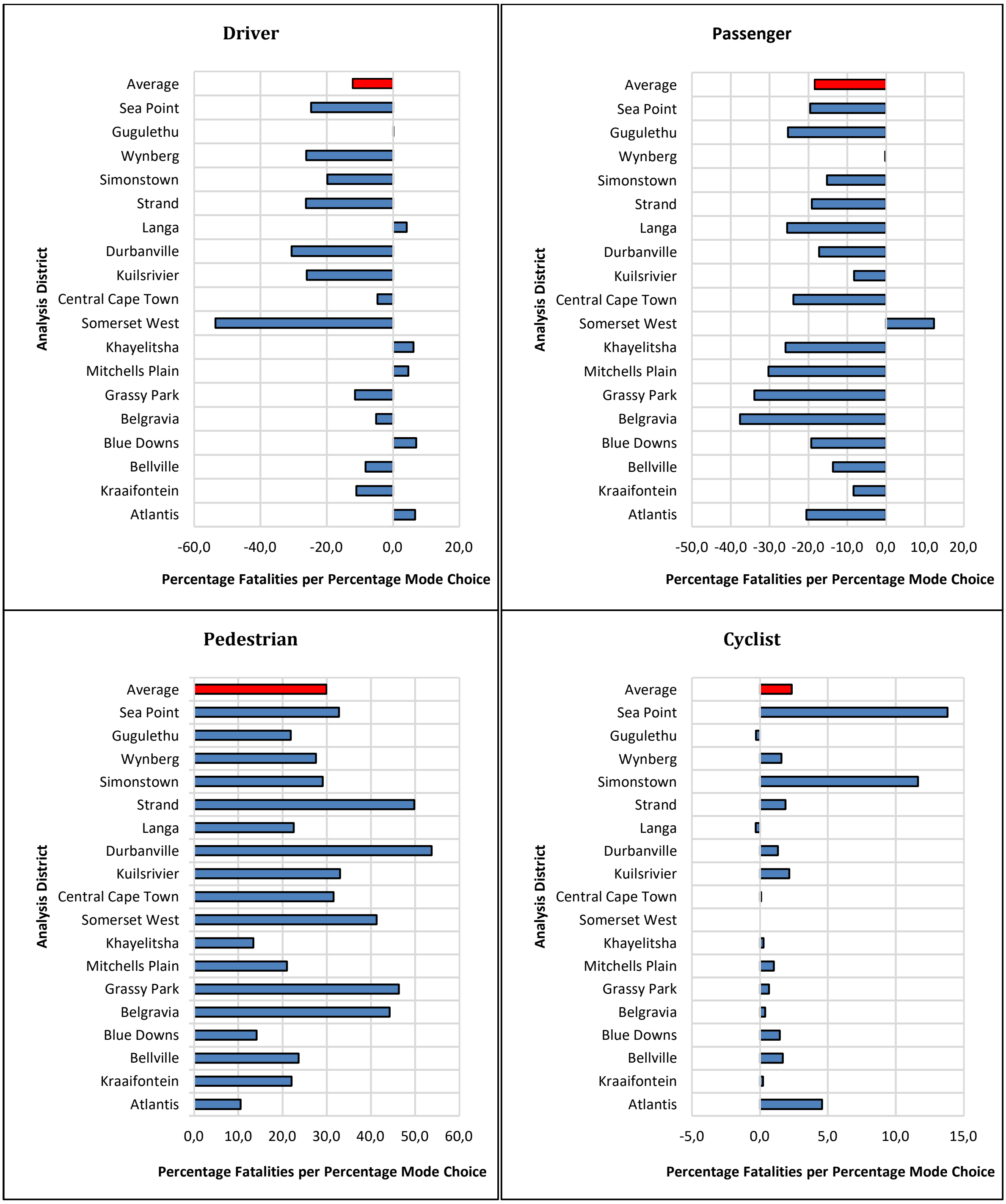

Figure 4-6: Percentage difference between mode usage and fatalities

Data Source: NHTS, 2013 and FPS, 2011-2015

The driver and passenger graphs in Figure 4-6 have an overall negative percentage, indicating that percentage fatalities affecting these two road user groups are less than the respective percentage mode users in Cape Town. Alternatively, the graphs of pedestrians and cyclists have an overall positive difference, indicating that percentage pedestrian and cyclist fatalities are higher than their respective percentage mode users in Cape Town. This result also suggests that pedestrians and cyclists are killed in areas close to their travel destinations rather than areas close to their households. However, a variation can be observed with the analysis districts, except in the case of pedestrians, for which all analysis districts have a positive difference. The passenger graph indicates that all districts have a negative difference with the exception of Somerset West (12.3%) where percentage passenger fatalities are higher than the percentage mode usage. Interestingly, in Wynberg, the percentage difference is almost zero at -0.2%, which suggests that the proportion of passenger road deaths are almost equal to the proportion of people that travel as passengers.

In the case of drivers, a large variation is observed between the analysis districts whereby Sea Point (-23.4%), Wynberg (-26.2%), Simons Town (-19.9%), Strand (-26.3%), Durbanville (-30.6%), Kuilsrivier (-26%), Somerset West (-19.9%), Grassy Park (-11.5%), Bellville (-8.3%) and Kraaifontein (-11.1%) are observed to have a negative percentage with the other analysis districts having a positive difference. In terms of cyclist fatalities and mode usage, all analysis districts are observed to have a positive difference with the exception of Langa (-0.3%) and Gugulethu (-0.3%). Two analysis districts – Sea Point and Simons Town have significantly higher cyclist fatalities than their relative mode usage, while Somerset West has no cyclist fatalities or cycle users.

4.5 Average Annual Fatalities (AAF)

In terms of average annual fatalities, the analysis districts with the highest average annual fatalities over the five years are seen to be Bellville (68.8 fatalities/year), Blue Downs (76.2 fatalities/year), Mitchells Plain (62.2 fatalities/year), Khayelitsha (74.6 fatalities/year) and Central Cape Town (65.4 fatalities/year) (see Figure 4-7). The districts with the lowest average fatalities are observed to be Kuilsrivier (9.6 fatalities/year) and Sea Point (7.2 fatalities/year). The average annual fatalities for each road user group in each district are shown in Figure 4-8. The result deduces that, on average, approximately 637 road users died due to a road traffic crash from 2011 to 2015, with approximately 367 (out of 637) road deaths impacting pedestrians, 108 road deaths impacting drivers and 104 road deaths impacting passengers. In terms of each analysis district, the results are similar to the findings in section 4.2, as would be expected.

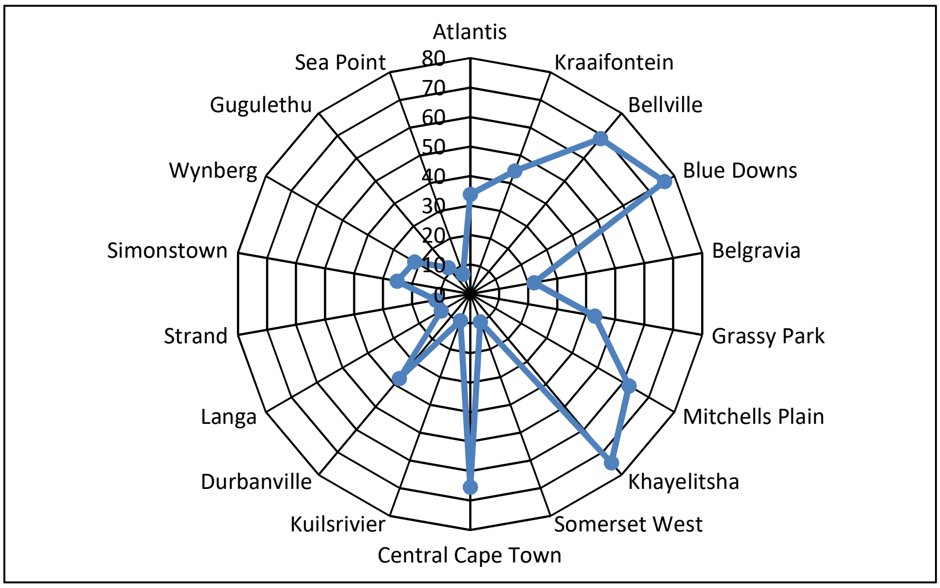

Figure 4-7: Average Annual Fatalities in each district

Data Source: FPS data, 2011-2015

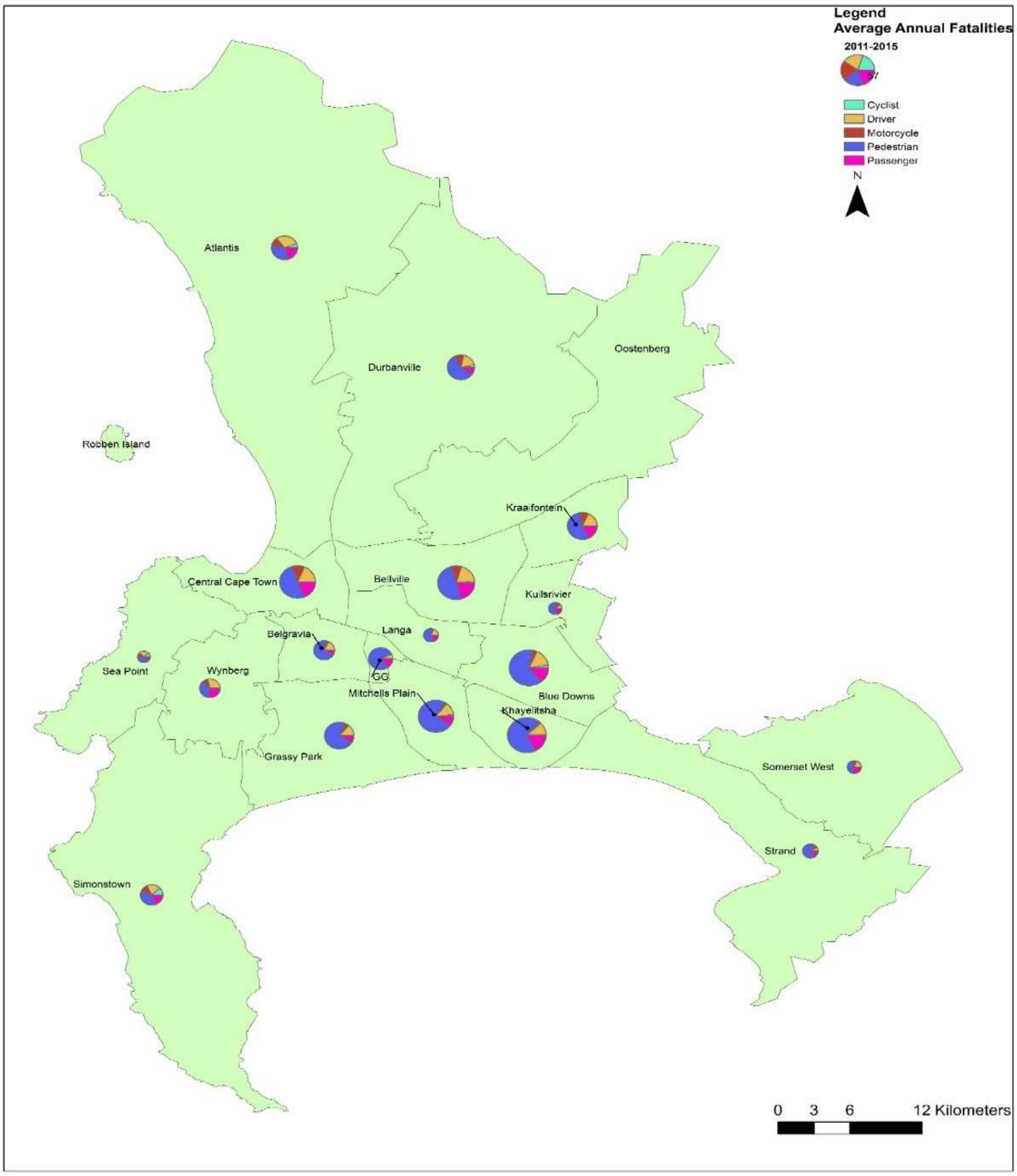

Figure 4-8: Average Annual Fatalities for each road user group

Data Source: FPS, 2011-2015

4.6 Average Annual Fatalities per 100 000 Population

Figures 4-9 and 4-10 show the average annual fatalities per 100 000 population (also called the fatality rate) in each district, and the fatality rate for each road user group in each district, respectively. Comparing these two figures to Figures 4-7 and 4-8, respectively, suggests that a completely different perspective can be obtained, when the population of the district is considered in the form of fatality rates. For instance, the analysis districts of Bellville, Blue Downs, Mitchells Plain, and Khayelitsha, that had previously been observed to have high average annual fatalities (see Figures 4-7 and 4-8) are seen to have comparatively low fatality rates. The exception to this trend is Central Cape Town, which is seen to have high average fatalities per year and high fatality rates at 65.4 fatalities per year and 50.8 fatalities per 100 000 population.

The fatality rate in Durbanville is observed to be the highest at 70.4 fatalities per 100 000 population followed by Central Cape Town (50.8 fatalities per 100 000 population) and Somerset West (28.9 fatalities per 100 000 population), respectively. Alternatively, Kuilsrivier, Langa, Strand and Sea Point are seen to have low fatality rates of less than 10, comparable to first world countries such as Australia, Japan and The Netherlands (as seen in Table 2-1).

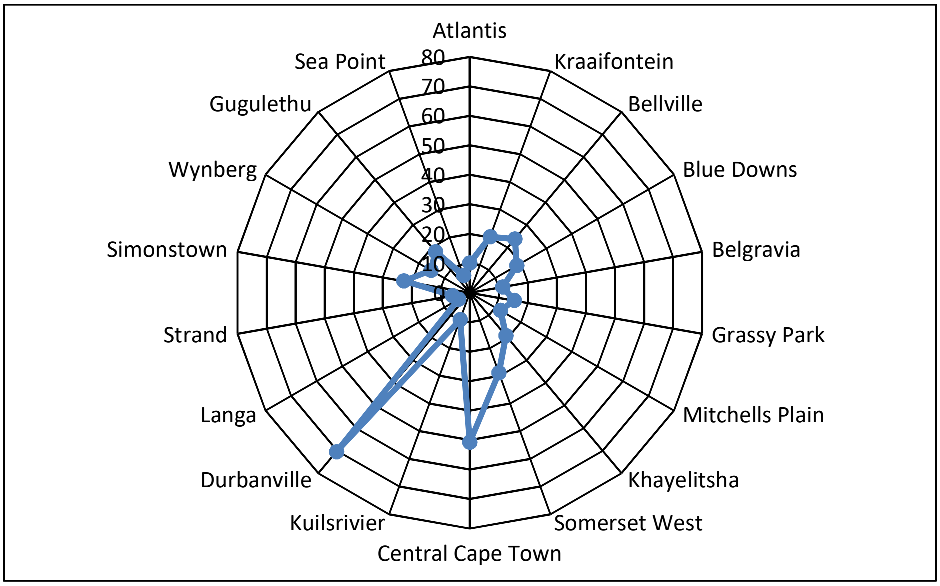

Figure 4-9: Average Annual Fatalities per 100 000 population in each district

Data Source: FPS, 2011-2015

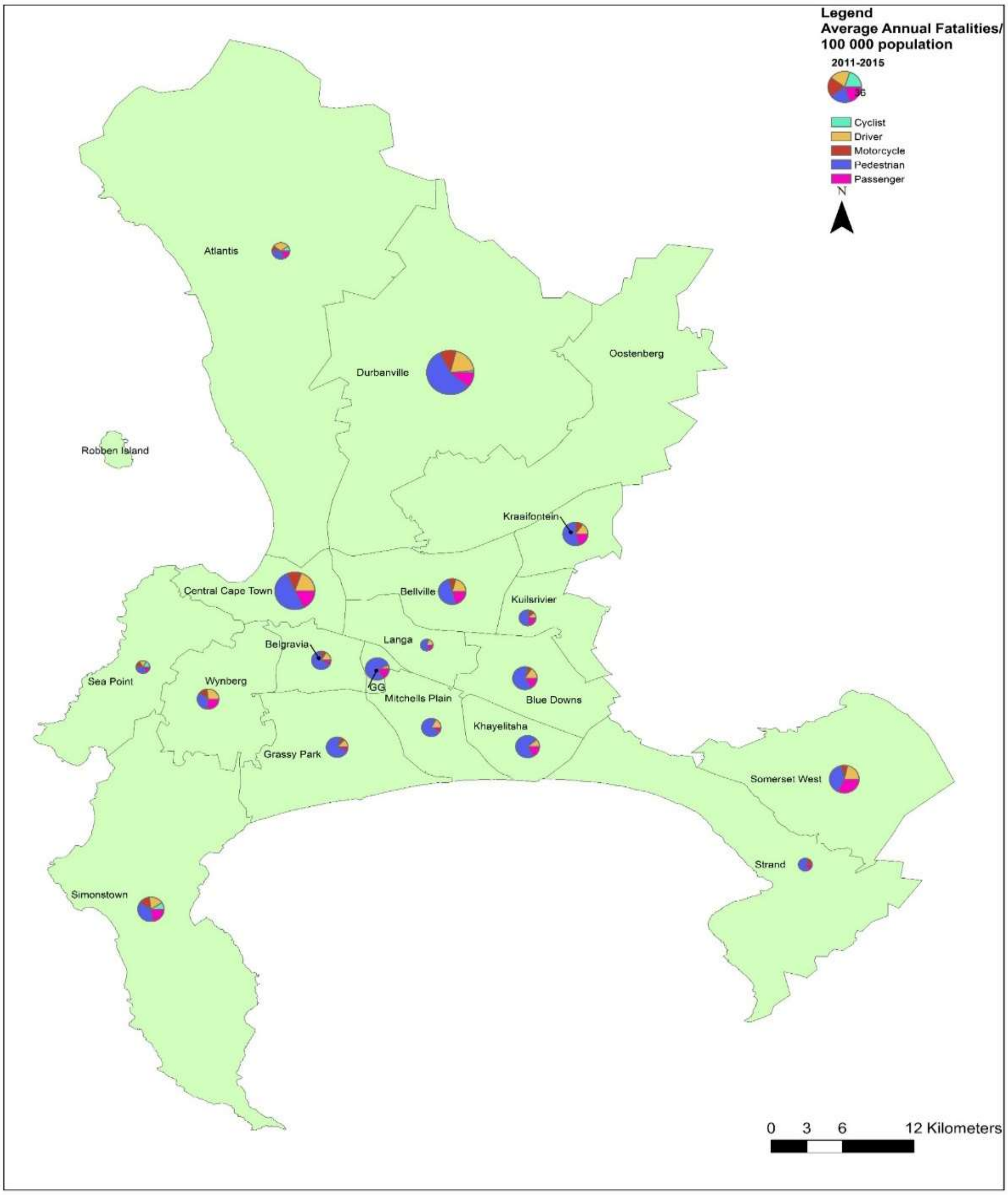

Figure 4-10: Fatality rate for each road user group

Data Source: FPS, 2011-2015

4.7 Fatality Rate/100 000 versus Average Annual Fatalities

The results in the previous two sections deduce that the situation in an analysis district can vary depending on the variable used i.e. whether fatalities per year are considered or average annual fatalities per 100 000 population. Hence, the analysis in this section aims to combine the two variables, with the fatality rates on the Y-axis and the average annual fatalities on the X-axis in order to clearly compare the two variables for each district (see Figure 4-11). Figure 4-11 also shows the average fatality rates of the World (17.1) and African Countries (24.1) for comparison purposes. The results will also infer the income variation between analysis districts (as seen in Table 3-2) to illustrate how income plays a role in fatalities observed.

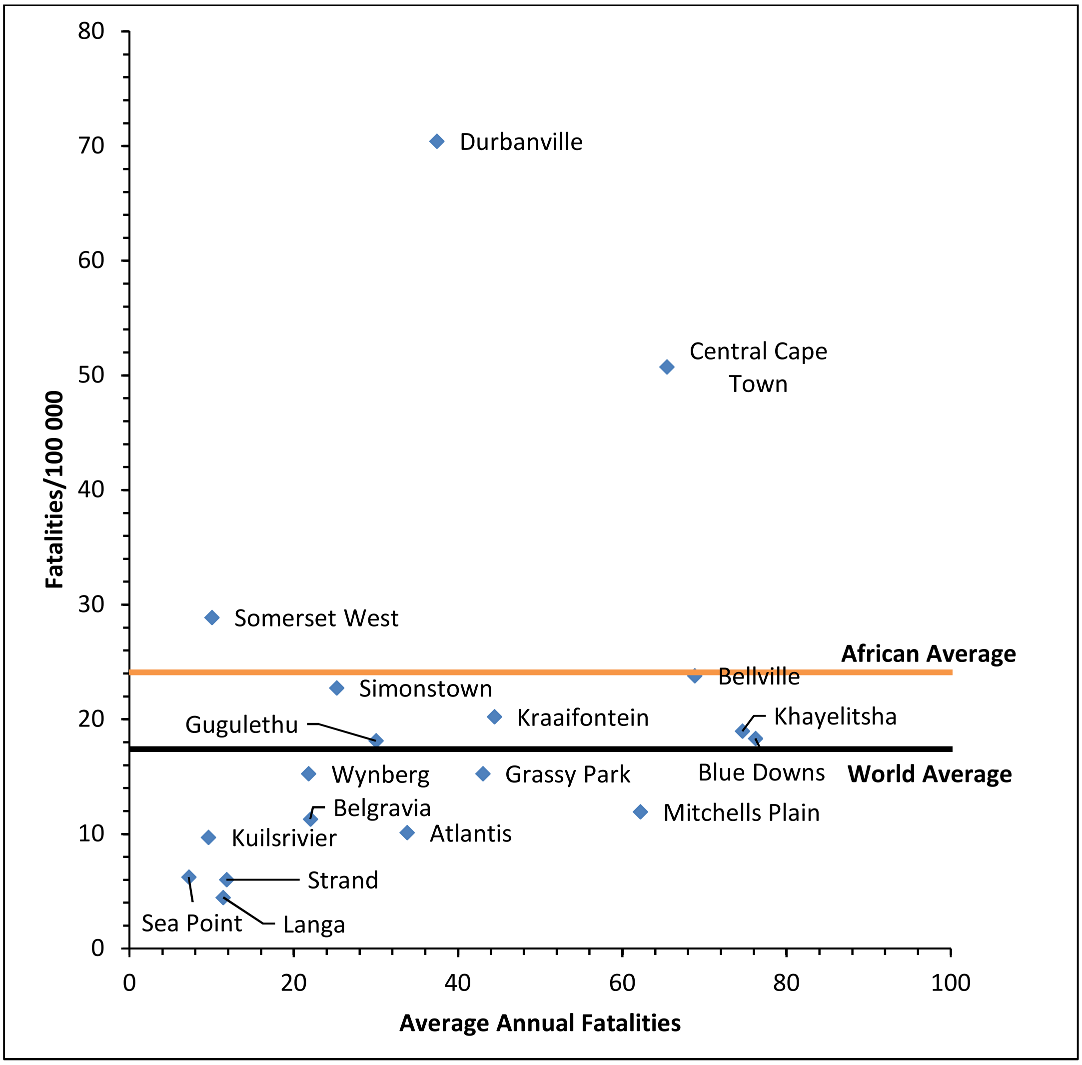

Figure 4-11: Fatality Rate versus Average Annual Fatalities

Data Source: FPS, 2011-2015

Three analysis districts are seen to have fatality rates higher than the African average of 24.1 fatalities per 100 000 population, namely Durbanville, Central Cape Town and Somerset West. In the case of Durbanville and Somerset West, where majority of the population falls in the high-income[14] category, the fatality rates are seen to be higher than the average annual fatalities. However, in Central Cape Town, where the majority of the population also falls in the high-income category, both the fatality rate and the average annual fatality is observed to be high. As mentioned previously, the mortuary location in Central Cape Town may have had an impact on this finding.

The rest of the 16 analysis districts have fatality rates that are less than the African Average. However, in the case of six districts, the fatality rates are higher than the World Average of 17.1 fatalities per 100 000 population, namely Simons Town, Kraaifontein, Bellville and the three townships of Gugulethu, Khayelitsha and Blue Downs. Bellville, a high-income area, together with Khayelitsha and Blue Downs, low-income areas, are seen to have comparatively higher average annual fatalities than

[14] A high-income district is described as a district where majority of the households earn a monthly income of ZAR 8 000 or more based on the income distribution in the city (see Table 3-2). A low-income district is therefore described as a district where majority of the households earn a monthly income of less than ZAR 8 000.

fatality rates. On the other hand, low-income areas of Gugulethu and Kraaifontein, together with Simons Town, a high-income area, are seen to have comparatively high fatality rates than average annual fatalities. Another township and low-income area, Mitchells Plain, is also seen to have an interesting result whereby the fatality rate in the district is less than the World Average, but the average number of fatalities per year is seen to be very high (approximately 62 fatalities per year).

Overall, low-income areas, with the exception of Gugulethu, have low fatality rates but high average annual fatalities. Conversely, in high-income areas, with the exception of Bellville and Central Cape Town, the fatality rates are high while the average fatalities per year are low. As mentioned previously, in the case of Central Cape Town, both the fatality rates and average fatalities per year are seen to be very high. From this analysis, it can be inferred that both variables – fatality rates and average annual fatalities – need to be determined when performing a road safety analysis for a thorough understanding of the road safety status quo in the city.

4.8 Vehicle Involved in Fatalities

Data from the previous sections provided an insight into the road user fatalities in the nineteen districts. In addition to the fatalities data provided for the five road user groups, the FPS data obtained, also provided information on the vehicles involved in the various fatalities. These vehicles were categorised into six, namely, Bakkie, Bus, Minibus Taxi, Motorbike, Sedan, and Truck. In certain cases, the dataset provided no vehicle information because of missing data. In these cases, the field showed the vehicle involved as “other”, “unknown” or “blank”.

In Cape Town overall, the percentage of vehicle data that is missing, amounts to 54% with only 46% of data available for analysis (see Figure 4-12). In terms of the analysis district, the percentage of missing data varies from 38% in Atlantis to 67% in Sea Point (see Figure 4-13). While none of these designations provide any information, it is interesting to note that the percentage of “blank” data is comparatively higher for all analysis districts. This finding suggests that the information on vehicles involved is not recorded, generally, during a fatality incidence. With such a large percentage of missing vehicle data, any analysis performed would not represent the actual risk per vehicle type at a disaggregated level, hence, the analysis was discarded.

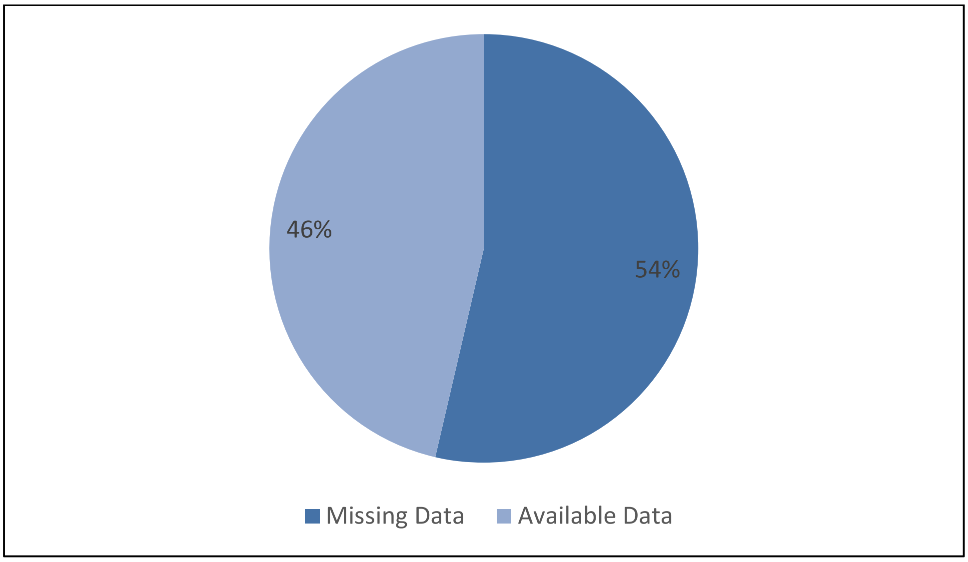

Figure 4-12: Percentage vehicle data that is missing and available

Data Source: FPS, 2011-2015

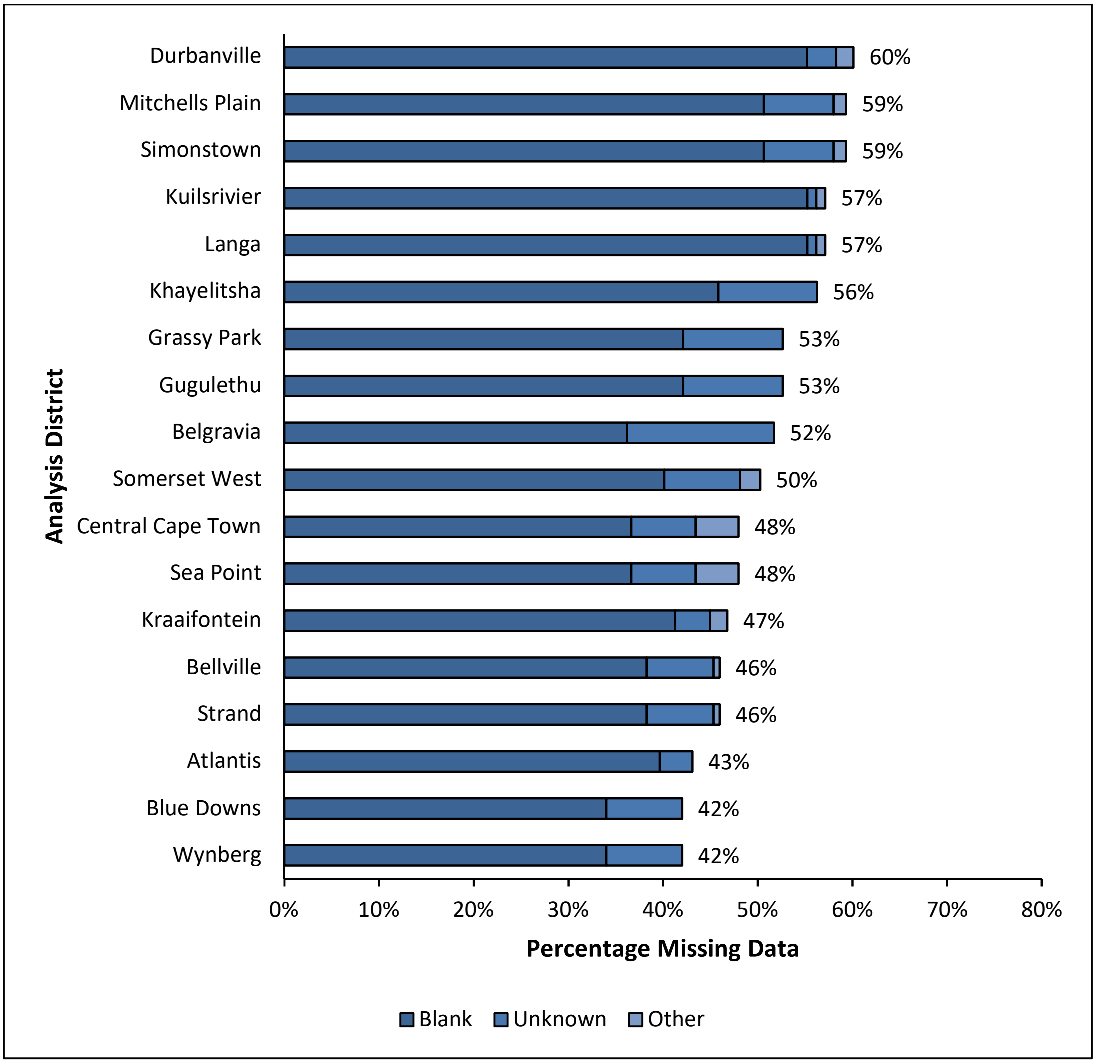

Figure 4-13: Percentage vehicle data that is missing

Data Source: FPS, 2011-2015

However, as seen in section 2-3, Jungu-Omara and Vanderschuren (2006) provide insight on the accident risk per registered vehicle. The study found that sedans are involved in majority of the accidents (66%). The risk attached to this vehicle is low though (0.16) and MBTs are seen to have the highest risk per registered vehicle type (0.88). Studies in other African countries also suggest that paratransit services expose passengers to high risk of injuries and are accountable for high passenger deaths (see, for instance, Nantulya and Reich, 2003; Odero *et al.*, 2003 and Afukaar *et al.*, 2016). As mentioned previously, this risk is caused by driver sleep deprivation, vehicle overloading and reckless driving.

4.9 Fatality Location

In this analysis, the top 10 hazardous zones were identified based on the fatality numbers using FPS (2015) and iPAS (2011-2015). Two GIS maps were created to show the results with the zone size proportional to the number of fatalities – the first map shows the hazardous zones on a district map (see Figure 4-14) and the second map shows the hazardous zones on a road map (see Figure 4-15). The FPS data identified hazardous zones in Central Cape Town, Bellville, Blue Downs, Khayelitsha and Sea Point. In this case, Blue Downs contained the highest number of hazardous zones, i.e. 4 zones, followed by Khayelitsha (two zones) and Bellville (two zones). Alternatively, iPAS data identified hazardous zones in Central Cape Town, Bellville, Durbanville and Langa. Based on this dataset, the most hazardous zones are found to be on the border of the districts along the national roads, however, some hazardous zones are also found in Central Cape Town (two zones) and Bellville (two zones).

The FPS data showed that all 10 zones have had six fatalities or more in 2015. However, further analysis of the FPS data showed a large number of anomalies. For instance, the most hazardous zone location in Bellville with 48 fatalities, is located at Tygerberg Hospital. As stated previously, when fatality locations are unknown, FPS data collectors designate the mortuary or hospital coordinates to the fatalities, which resulted in this anomaly. The FPS dataset also showed incorrect data entries. This was found to be the case in Blue Downs, for instance, where one crash showed six driver fatalities and six passenger fatalities. This is obviously incorrect and, presumably, one crash occurred in the location that led to six fatalities with one driver and five passengers killed. These findings, together with the results in the previous section, signify that in the case of fatality conditions, FPS data is incomplete and contains various anomalies.

As a result, the analysis in this section was limited to iPAS data alone. This dataset also contains missing data and does not cover all areas, however, this is the best dataset available in the Western Cape Province. Based on this dataset, the number of fatalities vary from 37 fatalities at the N1-N7 junction to 3 fatalities on the N2 and the N7. As mentioned previously, detailed description on the fatality conditions is provided for the top three zones due to the study limitations, where on average two fatalities or more fatalities occurred in the past five years. The conditions that led to the high number of fatalities in these areas are described after Figure 4-15, accompanied with Google Earth images for a clearer picture of the surroundings. For the other seven areas, Google Earth images are also provided in the Appendix.

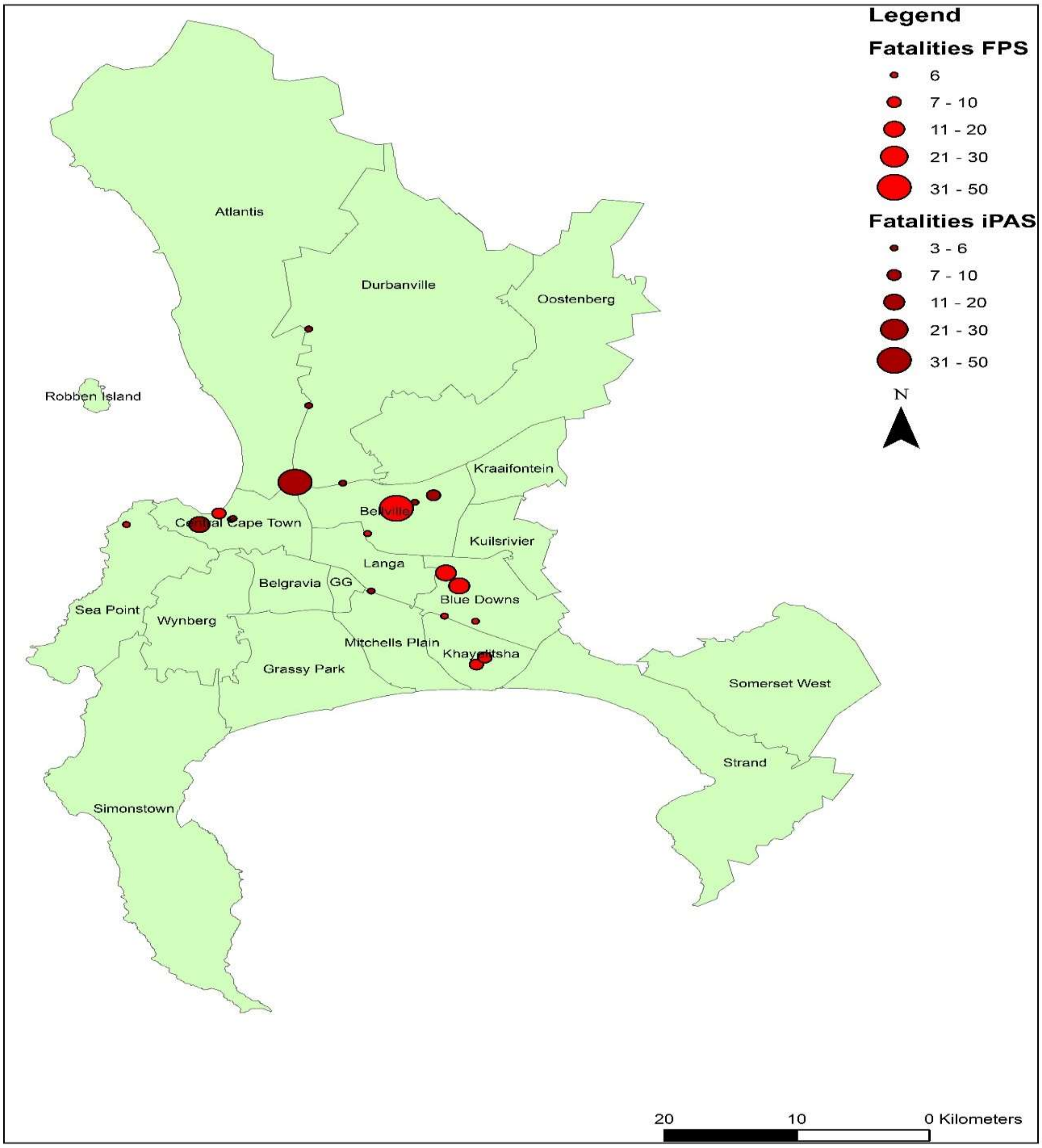

Figure 4-14: Top 10 hazardous areas in Cape Town on the district map

Data Source: iPAS, 2011-2015 and FPS, 2015

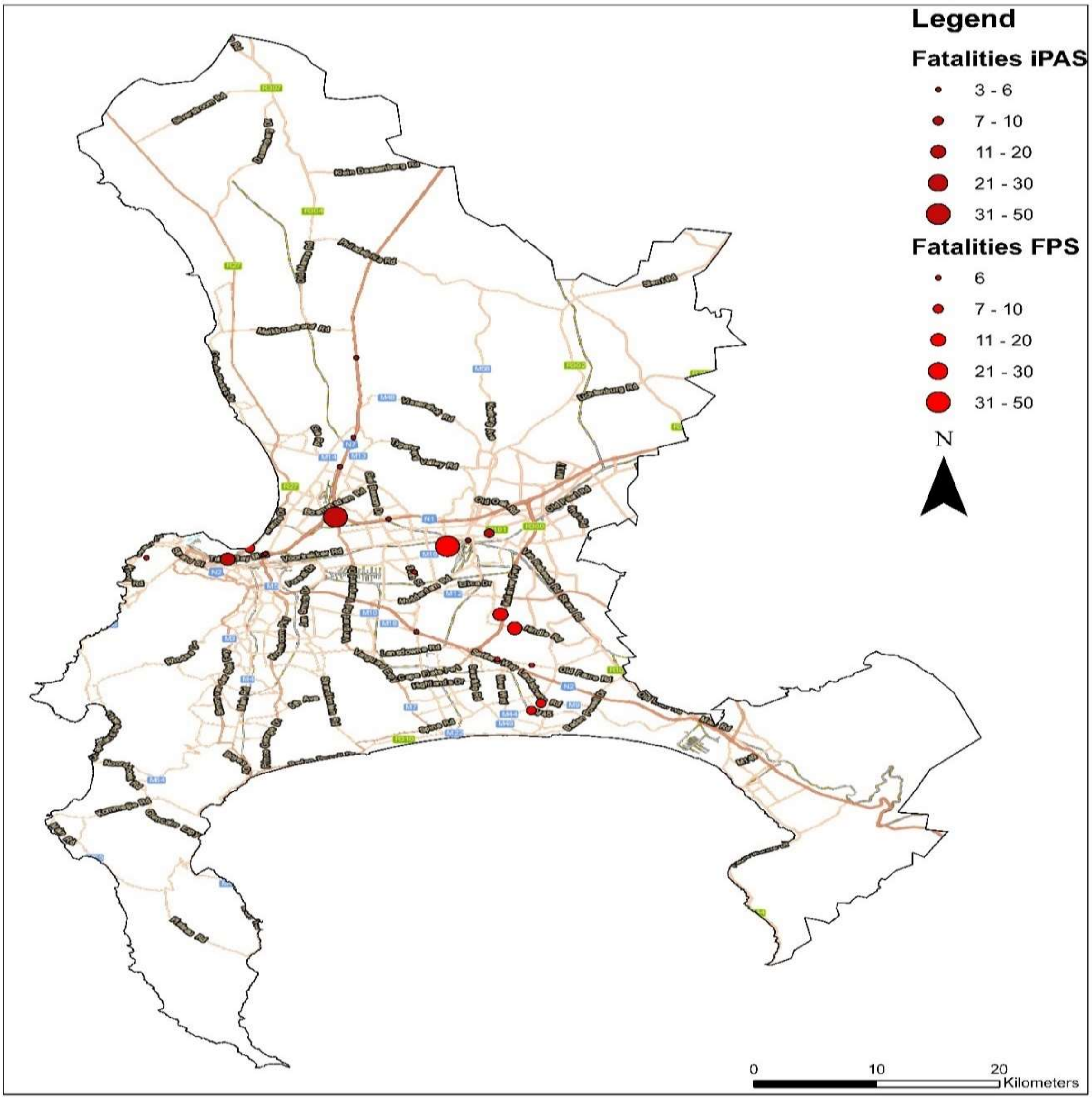

Figure 4-15: Top 10 hazardous areas in Cape Town on the road map
Data Source: iPAS, 2011-2015 and FPS, 2015

4.9.1 N1 and N7 Junction

The most hazardous location is the intersection of two national roads – N1 and N7 (see Figure 4-16). A total of 618 crashes occurred in this location with 33 crashes resulting in 37 fatalities (see Table 4-1). Both roads have a speed limit of 120 km/h and majority of these fatalities were pedestrian fatalities (57%). Only fifteen fatal accidents occurred during the day with the majority (59%) occurring during periods where vision is impaired (dusk, dawn or night). Previous studies in South Africa have also found that majority of road fatalities occur during periods of vision impairment (see, for instance, Mabunda *et al.*, 2008 and Das, 2014) The highest number of fatalities (10 fatalities) occurred on a Friday with 38% of fatalities transpiring during the weekend. Risky or unsafe driver behaviour resulted in over half of the fatal crashes (51.5%), while three fatalities involved drunk pedestrians.

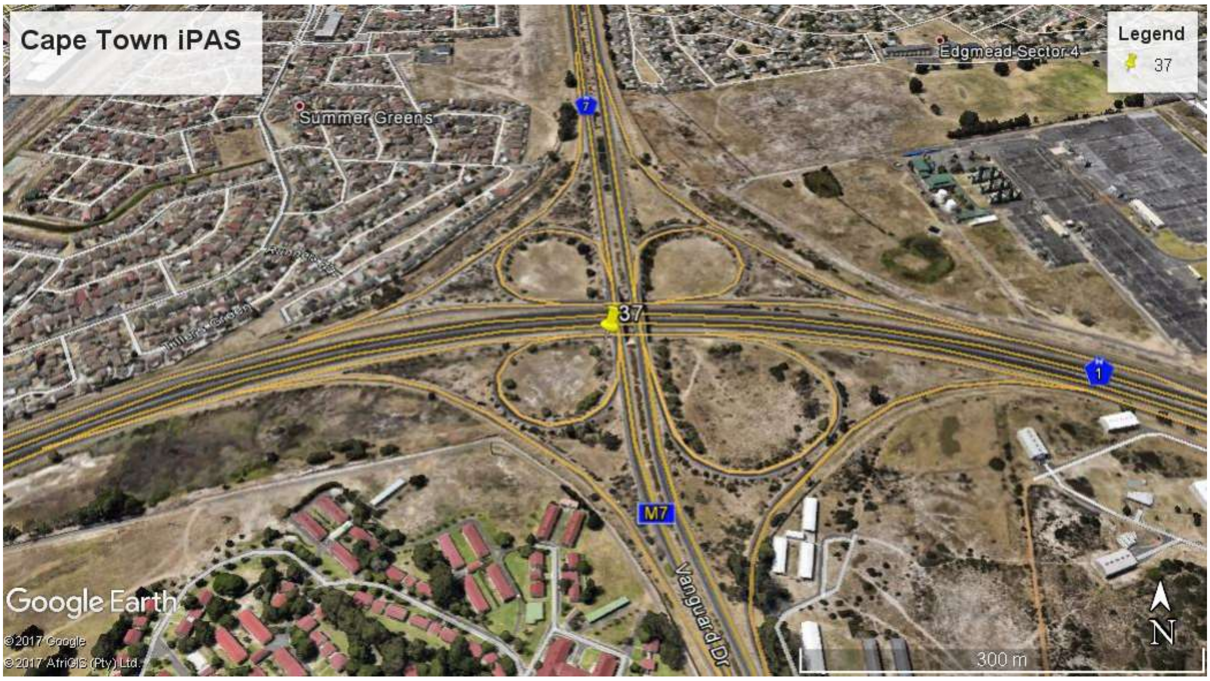

Figure 4-16: Hazardous location in Cape Town where 37 fatalities occurred

Source: iPAS data, 2011-2015 and Google Earth Pro (2017)

Table 4-1: Crash and Fatality information at Top 1 Location in Cape Town

Field Description	Value
Number of crashes	618
Number of fatal crashes	33
Number of fatalities	37
Number of injuries	943
Number of cyclist fatalities	1
Number of pedestrian fatalities	21
Number of pedestrian injuries	38
Percentage of fatal crashes during the day	40.5%
Percentage of fatal crashes during dry conditions	81.2%
Percentage of fatal crashes without any obstructions	51.5%
Percentage of fatal crashes on a straight	84.8%
Percentage of fatal crashes part of the road with good road signage	84.8%
Percentage of fatal crashes due to risky or bad driver behaviour	51.5%
Percentage of speed during fatal crashes: • 60km/h • 80km/h • 120km/h • unknown	3% 3% 57.6% 36.4%
Percentage of fatal crashes, due to other: drunk pedestrian + tyre burst	3% + 3%

Data Source: iPAS, 2011-2015

The findings in this scenario are in accordance with previous assumptions by Behrens (2005) who stated that, because pedestrians in Cape Town are walking long distances, they are likely to cross high-speed arterials, which increases the likelihood of a fatality crash. Based on the literature review of best practices, in this case it is suggested that a pedestrian bridge is provided for safer crossing. However, pedestrians do not generally use crossings, since these facilities deviate from the pedestrian desire line and require an extra walking distance (Chu *et al.*, 2004). Therefore, in order to tackle this, an infrastructure audit should be performed in this area to define a pedestrian desire line and implement an overpass at a convenient location (Slingers, 2012). The infrastructure would also assist in determining why such a large number of crashes (618) occur in this area. Mutto *et al.* (2002) found that pedestrians also do not use crossing facilities, because many users do not think that an overpass is an appropriate method of avoiding traffic accidents. This suggests that a combined intervention is required that includes campaigns for educating road users and stringent enforcement that ensures road users comply with the law.

The causes of the fatal crashes suggest that driver behaviour and lack of adequate street lighting add to the problem in majority of the fatalities. In the case of the former cause, stricter enforcement on drivers is recommended. While, in the case of the latter cause, lighting conditions need to improve to provide adequate visibility. As mentioned previously, Vanderschuren *et al*. (2017) found that lighting is a cost-effective measure that can reduce the incidence of crashes.

4.9.2 Table Bay Boulevard (N1)

The second most hazardous location is found along Table Bay Boulevard (N1) (see Figure 4-17). A total of 173 crashes transpired in this location with eight fatal crashes resulting in 17 fatalities that includes one pedestrian fatality (see Table 4-2). A little over half of the fatalities (53%) occurred during periods of vision impairment (dusk, dawn or night). Majority of the fatalities (82%) occurred during the weekends. In 62.5% of fatal crashes, risky driver behaviour caused the crash. Furthermore, one fatality was caused by a tyre burst and another one caused by a pedestrian.

Figure 4-17: Hazardous location in Cape Town where 17 fatalities occurred
Source: iPAS data, 2011-2015 and Google Earth Pro (2017)

Table 4-2: Crash and Fatality information at Top 2 Location in Cape Town

Field Description	Value
Number of crashes	173
Number of fatal crashes	8
Number of fatalities	17
Number of injuries	205
Number of cyclist fatalities	0
Number of pedestrian fatalities	1
Number of pedestrian injuries	2
Percentage of fatal crashes during the day	50%
Percentage of fatal crashes during dry conditions	87.5%
Percentage of fatal crashes without any obstructions	87.5%
Percentage of fatal crashes on a straight	87.5%
Percentage of fatal crashes part of the road with good road signage	75%
Percentage of fatal crashes due to risky or bad driver behaviour	62.5%
Percentage of speed during fatal crashes: • 120 km/h • unknown	 87.5% 12.5%
Percentage of fatal crashes, due to other: drunk pedestrian + tyre burst	12.5% + 12.5%

Data Source: iPAS, 2011-2015

The findings in this scenario with regards to street lighting and driver behaviour, are similar to the findings in the previous location. Consequently, the recommendations are similar to the ones provided in the previous hazardous zone, in order to tackle driver behaviour and vision impairment. An infrastructure audit also needs to be performed in this area to identify the cause of the high number of crashes (173) and to determine the reasons for the fatal crashes.

4.9.3 Bill Bezuidenhout Avenue (M30) and Old Paarl Road (R101)

The third most hazardous location is the intersection of Bill Bezuidenhout Avenue (M30) and Old Paarl Road (R101) (see Figure 4-18). A total of 10 fatalities in this location occurred in 9 fatal crashes (see Table 4-3). The majority of the fatalities (60%) involved pedestrians with two other fatal crashes affecting cyclists. Only four fatalities occurred during the day with the majority (60%) transpiring during periods of vision impairment (dusk, dawn or night). Risky driver behaviour was not found to be the cause of fatalities in this location. In the case of this location, the speed limits on the roads were found to be 60 km/h on the M30 and 80 km/h on the R101.

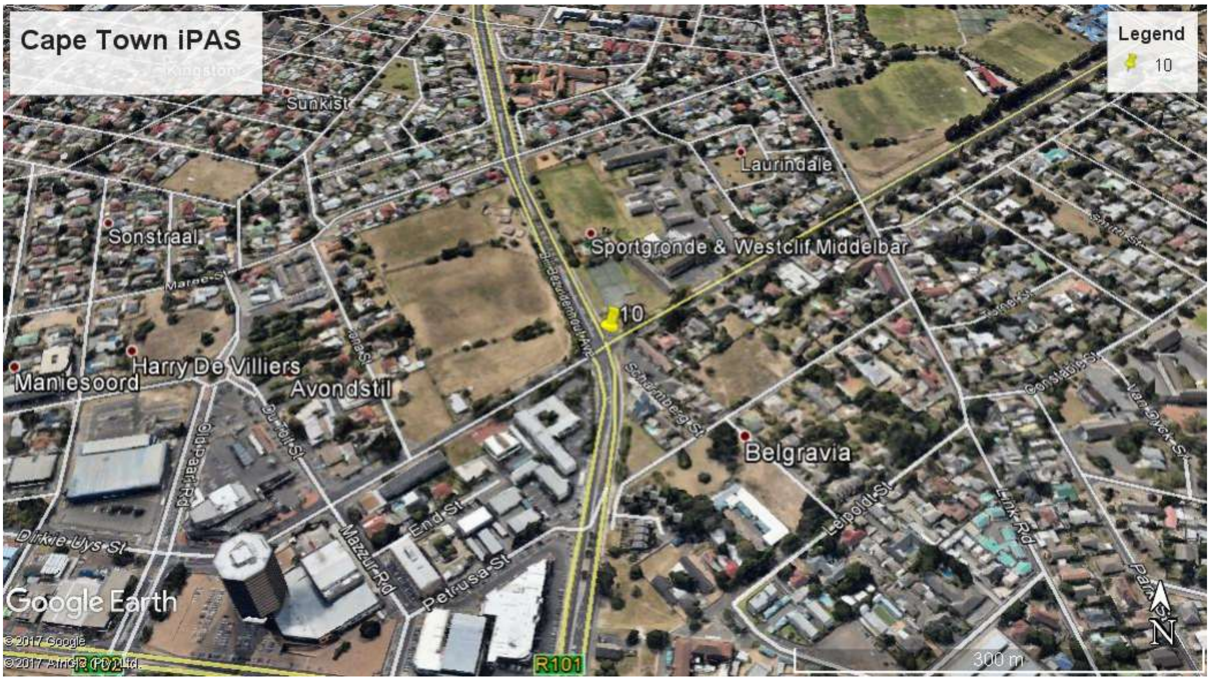

Figure 4-18: Hazardous location in Cape Town where 10 fatalities occurred

Source: iPAS data, 2011-2015 and Google Earth Pro (2017)

Table 4-3: Crash and Fatality information at Top 3 Location in Cape Town

Field Description	Value
Number of crashes	152
Number of fatal crashes	9
Number of fatalities	10
Number of injuries	240
Number of cyclist fatalities	2
Number of pedestrian fatalities	6
Number of pedestrian injuries	7
Percentage of fatal crashes during the day	44.4%
Percentage of fatal crashes during dry conditions	77.8%
Percentage of fatal crashes without any obstructions	22.2%
Percentage of fatal crashes on a straight	66.7%
Percentage of fatal crashes part of the road with good road signage	100%
Percentage of fatal crashes due to risky or bad driver behaviour	22.2%
Percentage of speed during fatal crashes: • 80km/h • 100km/h • unknown	 11.1% 77.8% 11.1%
Percentage of fatal crashes, due to other: N/A	0%

Perusal of Figure 4-18 shows that these two roadways run through residential areas. The speed limits in this location are high for this residential area, hence, a speed reduction is required. The literature reviewed in this study showed that speed limits have had positive impacts in the case of many countries (see, for instance, Waiz *et al.*, 1983 and McLean *et al.*, 1994). As mentioned previously, South Africa has adopted new speed limits in 2017 for residential areas (BusinessTech, 2017) and the new speed limits should also be adopted, according to law, for these two roads.

The infrastructure can also play a role in this location, as found by Vanderschuren and Jobanputra (2009). These infrastructure improvements include a raised intersection, traffic circles and roadway narrowing. Similar to the previous scenarios, an infrastructure audit is recommended to identify the correct alternative. The fatal crashes, in this case, also occurred during periods of vision impairment. As a result, lighting is also recommended for this scenario.

4.10 Summary of Chapter

In the five years analysed, Cape Town recorded an average of 667 fatalities per year. Analysis showed that annual fatalities initially decreased in the first four years, but increased in the final year i.e. 2014 to 2015 (see Figure 4-1). A comparison of road user fatalities in Cape Town and Western Cape (see Figure 4-2) suggests that the former has a higher portion of pedestrian fatalities (58% vs 46%) while the latter has a higher portion of automobile fatalities i.e. passengers and drivers (33% vs 46%).

Regarding the analysis districts, road users are the most affected in Blue Downs, Khayelitsha, Bellville, Central Cape Town and Mitchells Plain where over 300 fatalities were recorded (see Figure 4-3). Furthermore, pedestrians are observed to be the most vulnerable group in all districts, with drivers and passengers being the second or third most vulnerable group depending on the analysis district considered. The results of the fatalities versus mode usage analysis showed that percentage of pedestrians and cyclists fatalities are higher than the percentage of the Cape Town population that walk and cycle, respectively (see Figure 4-6). Alternatively, the percentage of driver and passenger fatalities are less than the respective mode users, in terms of percentage, in Cape Town.

Moreover, in low-income analysis districts, the average annual fatalities are observed to be comparatively higher than the fatality rates in these districts (see Figure 4-11) and the opposite is true for high-income analysis districts. In terms of vehicles involved in fatalities, the FPS data contained a large percentage of missing data (54%) and since any analysis performed would not represent most of the fatalities, the results were therefore discarded.

Lastly, the geocoded data analysis was limited to iPAS data since the FPS data, similar to the vehicle data, showed a large set of anomalies and missing data. The iPAS data showed hazardous zones in Central Cape Town, Bellville, Durbanville and Langa mainly along national roads. The fatalities in the top three zones varied from 37 to 10 with pedestrians observed the most affected group in two zones – N1 and N7 junction and M30 and R101 intersection. The majority of the fatalities occurred during periods of vision impairment with the dataset suggesting that risky driver behaviour caused most of the fatalities. Based on the findings, it is recommended that pedestrian crossing facilities are provided along pedestrian desired lines, speed limits are reduced along residential roads and adequate lighting is provided to improve roadway visibility.

5. CONCLUSION

This Chapter discusses the conclusions and recommendations of this study. The research questions identified in section 1.4 are first discussed followed by an explanation on the implications of this study's findings and improvements to the study. Lastly, a brief description is provided on the further applications of the study's methodology and findings.

5.1 Research Questions

What is the current road safety status quo at a Worldwide, African, and National level?

Road Traffic Injuries (RTIs) claim more than 1.25 million lives each year, with the majority of those deaths affecting young adults aged 15-29 and vulnerable road users (World Health Organisation (WHO), 2015). The fatality burden is not equal though in terms of income of countries, with Low- and Middle-Income Countries (LMIC) having a higher fatality rate than the average fatality rates in the World and High-Income Countries (HIC). The road users affected in these countries also vary with majority of the fatalities in LMIC affecting pedestrians, cyclists and motorcyclists, while majority of the fatalities in HIC affect automobile drivers (Naci *et al.*, 2009). Therefore, pedestrians, cyclists and motorcyclists, in the case of LMIC, represent Vulnerable Road Users (VRUS). Since HIC have successfully managed to reduce VRUs fatalities, theory suggests that interventions applied in these countries can also be adopted in LMIC to protect VRUs further. However, because the travel patterns of the population in these two countries vary considerably, it is important to consider the context when adopting methods from HIC.

In the African continent, average fatality rates suggest that the risk of dying because of a Road Traffic Crash (RTC) is higher than in other continents (Peden et al., 2004). Similar to the findings in LMIC, the most affected road user groups in African countries are seen to be VRUs, who constitute 52% of road fatalities with pedestrian fatalities accounting for 37%. Data from Odero (1997, cited by Odero *et al.*, 2003) suggested that context is also crucial within a country, as the road users affected in urban areas may be different from road users affected in rural areas[15]. Overall, the literature inferred a number of reasons as to why the burden of fatalities in African countries is so high, with the main contributing factors considered to be limited Non-Motorised Transport (NMT) facilities, inadequate public transport, increasing private vehicle growth and poor traffic safety regulations.

The fatality rate in South Africa is the second highest in the continent (31.9 per 100 000 population) after Nigeria (33.7 per 100 000 population). Overall, pedestrians remain the most affected group in the country (RTMC, 2015). However, fatalities per annum vary depending on the province considered (Vanderschuren *et al.*, forthcoming). From the literature reviewed, a gap was found in South Africa in terms of analysing the localised road safety burden within a city. Therefore, in this study, the road fatalities in Cape Town were unpacked at a more disaggregated level to fill this gap.

[15] See section 2.2 where fatalities in Nyanza (a rural area) varied from fatalities in Nairobi (an urban area).

In terms of total fatalities in the five years analysed, what is the relative impact on each road user group?

Over the five years analysed in this study, more than 300 fatalities occurred in Bellville, Blue Downs, Central Cape Town, Khayelitsha and Mitchells Plain while Grassy Park and Kraaifontein had over 200 road fatalities (see Figure 4-3). In terms of road user fatalities, pedestrians are the most vulnerable group in all districts constituting 58% of road fatalities with more than 200 pedestrians killed in Blue Downs, Khayelitsha and Mitchells Plain. The second and third most affected group are drivers (17%) and passengers (16%), respectively. However, this order varies depending on the district considered and in majority of the analysis districts, 11 of the 19, passengers are more vulnerable than drivers. Lastly, the fourth and fifth most affected group in Cape Town are motorcyclists and cyclists constituting of 7% and 2% of road fatalities, respectively.

Is the percentage death toll for the various road user types positive or negative, when compared to percentage mode usage for the various districts?

Findings from the analysis (see Figure 4-6) showed that in Cape Town, the percentage of people that travel as drivers and passengers are more than the percentage of fatalities that affect these two road user groups. The opposite is true in the case of pedestrians and cyclists. When considering the districts specifically, a few exceptions can be observed to this trend in the case of all road user groups with the exception of pedestrians. In the case of passengers, all analysis districts, except for Somerset West, have a higher proportion of passenger fatalities than proportion of population that travels as passengers. Alternatively, when considering drivers and cyclists, low-income areas have a higher percentage of driver fatalities than the percentage of the population that drive. While, in high-income areas, the percentage of cyclist fatalities are more than the percentage of the population that cycles.

How do the Average Annual Fatalities and the Average Annual Fatalities per 100 000 population of the Cape Town districts compare to World and African Averages?

The two variables calculated showed distinctively differing results in the case of certain districts. Table 5-1 shows Average Annual Fatalities (AAF) and Average Annual Fatalities (AAF) per 100 000 population of analysis districts, where these variations were observed. As seen in the table, Atlantis, Kraaifontein, Bellville, Blue Downs, Grassy Park, Mitchells Plain and Khayelitsha have AAF per 100 000 population values that are less than three times the AAF values. It is important to note that in this case, majority of these districts are low-income areas. Alternatively, in Somerset West and Durbanville, it was found that the fatality rates are twice the AAF values. In this case, both the districts are high-income areas.

Table 5-1: AAF and Fatality rates of certain districts

Analysis District	Average Annual Fatalities (AAF)	Fatality Rate (per 100 000 population)
Atlantis	33.8	10.1
Kraaifontein	55.5	20.2
Bellville	68.8	23.8
Blue Downs	76.2	18.3
Grassy Park	53	15.3
Mitchells Plain	62.2	11.9
Khayelitsha	75.6	19
Somerset West	10	28.9
Durbanville	37.5	70.5

Data Source: FPS, 2011-2015

How does the Average Annual Fatalities (AAF) per 100 000 population of the Cape Town analysis districts compare to World and African Averages?

The fatality rates alone extracted interesting findings whereby, in the case of certain districts, fatality rates observed were comparable to fatality rates of HIC. Table 5-2 shows the fatality rates of these districts, together with fatality rates of Australia, Great Britain, The Netherlands and Sweden and average fatality rates of the World and African region for comparison purposes. The table shows that the fatality rates in Belgravia, Mitchells Plain, Kuilrivier, Langa, Strand, Simons Town and Sea Point are less than the World and African Averages. In the case of Strand and Sea Point, the fatality rates are even less than Great Britain, which has the lowest fatality rate among the four countries chosen for comparison in this scenario.

Table 5-2: Fatality rates of certain districts compared to international fatality rates

Area	Fatality Rate (per 100 000 population)
Belgravia	11.3
Mitchells Plain	11.9
Kuilsrivier	9.7
Langa	7.5
Strand	5.6
Simons Town	12.8
Sea Point	5.5
World Average	17.1
Africa Average	24.1
Australia	9.5
Great Britain	5.9
Netherlands	6.8
Sweden	6.7

Data Source: Peden et al. (2004), Peden et al. (2013) and WHO (2013)

Which vehicle types pose the greatest threat to the five road user groups on the road?

The Forensic Pathology Services (FPS) data contained a large number of missing vehicle data with only 46% of data available for analysis (see Figure 4-12). Generally, the Provincial Accident System (iPAS) data provides better information on fatality conditions and, presumably, this dataset may have better information on vehicle types involved in fatalities. In this case, no access was available to this dataset, hence, further analysis could not be performed. However, the literature review performed in this study did provide insight on this information. Jungu-Omara and Vanderschuren (2006) deduced that Sedans are involved in majority of road accidents (66%) in Cape Town but the risk for this vehicle type is only 0.16. Alternatively, Mini Bus Taxis (MBTs) are involved in 6.6% of accidents but have the highest risk per vehicle (0.88). Vehicle Kilometres Travelled (VKT) also influences the risk per vehicle since the VKTs affect the amount of time a vehicle spends on the road and is exposed to risk (Vanderschuren and Zuidgeest, 2017). For instance, MBTs undertake many trips per day and travel long distances as well, which may reduce the risk involved with these vehicles. However, since this data is not available for Cape Town, literature on this analysis could not be found.

Where are the high-risk zones in Cape Town located?

Initially, analysis to identify hazardous zones involved the use of FPS (2015) and iPAS (2011-2015). However, similar to the vehicular data, FPS showed missing data and a large number of anomalies, hence, analysis was limited to iPAS. Using the iPAS data, the top 10 hazardous locations in the city were identified by ranking zones in terms of fatality numbers (Elvik, 2007). A detailed description was then provided on the conditions that caused the fatalities in the top three zones. In these zones, an average of two or more fatalities occurred in the past five years.

a) <u>N1 and N7 junction:</u>
   In this area, it was found that 37 fatalities occurred due to 33 crashes. Pedestrians constituted majority of the fatalities (57%) with a large percentage of the 37 fatalities (59%) occurring during periods of vision impairment. Furthermore, risky or unsafe drive behaviour caused over half of the fatal crashes (51.5%).
b) <u>Table Bay Boulevard (N1):</u>
   Eight fatal crashes occurred in this location. Similar to location (a), majority of the fatal crashes (53%) in this location occurred during periods of vision impairment. Risk or unsafe driver behaviour was also found to be the cause of majority of the fatal crashes (62.5%).
c) <u>Bill Bezuidenhout Avenue (M30) and Old Paarl Road (R101) junction:</u>
   A total of 10 fatalities in this zone occurred in 9 fatal crashes. Similar to zone (a), majority of the fatalities (60%) in this location affected pedestrians whereas 20% involved cyclists. Similar to the previous two scenarios, a higher percentage of fatalities (60%) transpired during vision impairment periods.

Based on the literature available on road safety best practices, what localised interventions can be prescribed to reduce the fatalities in high-risk zones?

The ‘road safety best practices’ literature review in this study provided insight on interventions that could be recommended for the top three hazardous zones. For each hazardous zone, the summary of recommendations is provided below. Generally, for all three zones, it is recommended that road safety audits are performed for a better understanding of the problems on the ground.

a) N1 and N7 junction:
Firstly, the introduction of a pedestrian bridge is recommended along a pedestrian desire line that increases the likelihood of pedestrian usage (Slingers, 2012). The literature inferred that pedestrians are also unaware of the safety benefits of an overpass to crossing at grade (Mutto *et al.*, 2002). Hence, a packaged intervention is recommended in this case, that includes introduction of an overpass, road safety campaigns and stringent enforcements that prevent jaywalking. Secondly, stringent enforcement during periods of vision impairment is also recommended on drivers to curb risk driver behaviour. Lastly, lighting, that has been found to be a cost-effective measure (Vanderschuren *et al.*, 2017), is suggested to provide better visibility.

b) Table Bay Boulevard (N1):
Similar to (a), lighting and stringent driver law enforcement is recommended for this zone to curb the vision impairment and risky behaviour problems, respectively.

c) Bill Bezuidenhout Avenue (M30) and Old Paarl Road (R101) junction:
In this case, high speeds were assumed to be the problem. Both roads ran through residential areas with speed limits of 60 km/h and above. South Africa has recently recommended a speed reduction for roads that run through residential areas. It is presumed that the reduced speed limits will reduce the fatality risk and possibility, since similar reductions have had positive impacts in other countries (Waiz *et al.*, 1983 and McLean *et al.*, 1994). In addition to this, infrastructure improvements (raised intersection, traffic circles and roadway narrowing) that assist in speed reductions, are recommended. Similar to the previous two zones, improved lighting is suggested for this zone.

5.2 Implications of Results

This study provided information on the road safety status of Cape Town starting from an aggregated to a disaggregated level in Chapter 4. What then are the implications of these findings on the road safety interventions being implemented by the City? The first, obvious, implication of the study is that the road fatality burden in Cape Town is high with almost 670 fatalities occurring per year during the 2011-2015 period. Furthermore, the trend during this period shows that absolute fatalities are not decreasing every year, which consequently, suggests that interventions are not implemented correctly.

The second implication of this study is that the burden on all road user groups is not the same in the City and the ‘analysis districts’. Pedestrians constitute of majority of the fatalities (58%) in the City followed by drivers (17%) and passengers (16%) (see Figure 4-2). This order is partially different in South Africa where pedestrians still constitute the majority of the fatalities (37.6%), however, passengers are the second most affected group (32%) followed by drivers (27%) (RTMC, 2015). This comparison suggests that pedestrian fatality burden is higher in Cape Town than in South Africa (58% vs 37.6%). In terms of the analysis districts, pedestrians constitute the majority of the fatalities with certain districts having upwards of 200 pedestrian fatalities (see Blue Downs, Khayelitsha and Mitchells Plain in Figure 4-3). However, the second and third most affected group is either drivers or passengers depending on the analysis district considered. This suggests that road safety analysis at a disaggregated level, is important when determining the road user that should be targeted for interventions. This is especially true for LMIC where road safety budgets are extremely limited (Bishai *et al.*, 2003). Therefore, in Cape Town, pedestrian safety needs to be prioritised in terms of all interventions introduced.

The third implication of this study – given the findings that the percentage of pedestrians and cyclists killed are more than the percentage of people that use the respective modes in the analysis districts (with the opposite being true for drivers and motorcyclists) – is that road users are not necessarily killed in areas close to their homes, rather in areas close to their destination of travel. This finding of pedestrians corresponds to previous findings by Behrens (2005), who confirmed that pedestrians in Cape Town are walking more than 60 mins per day, crossing high speed arterials consequently crossing the analysis districts. Therefore, prescribed interventions that target pedestrians and cyclists need to be introduced in their travel destinations rather than the residential areas.

The fourth implication of this study – given the findings of AAF and AAF per 100 000 population per analysis district – is that the variable considered can change the priority of interventions introduced. For instance, if AAF is considered, Mitchells Plain, which has approximately 65 fatalities/year (see Figure 4-7), would be an area of major concern since this average is amongst the highest in the City. However, if AAF per 100 000 population is considered, Mitchells Plain that has 11.9 fatalities per 100 000 population would not be an area of concern (see Figure 4-9) because this average is below the World’s average (17.1), the African region’s average (24.1) and the South African average (33.1). (WHO, 2013 and Peden *et al.*, 2013). Hence, it is recommended that when unpacking road safety at any level, both AAF and AAF per 100 000 population are considered to determine areas of major concern.

The fifth implication of this study – given the findings in the top three hazardous zones in Cape Town where fatalities mainly affect pedestrians crossing high-speed arterials during periods of vision impairment – is that safe pedestrian crossing continues to remain the problem in the City. The literature suggests that amongst other interventions, reducing speed limits along residential roads (Waiz *et al.*, 1983 and McLean *et al.*, 1994), providing adequate lighting (Vanderschuren *et al.*, 2017) and creating safe crossing infrastructure along the pedestrian desire line (Slingers, 2012) can have a positive impact. Driver behaviour is also seen to be the cause of majority of the fatalities in the top two hazardous zones, which suggests that stringent traffic laws have to be introduced. The scope of this study did not include investigating the infrastructure in these areas, however, this would be important in all cases in order to understand the local problem.

The sixth implication of this study is that fatalities data have missing gaps which, consequently underrepresent the road safety burden in the City. This was found to be the case in data for fatalities, vehicles involved in fatalities and geocoded fatalities. In terms of the fatalities data, no South African Police Service (SAPS) could be allocated to Overberg, where 3.7% of the Cape Town population resides. This meant that this study did not report on fatalities affecting this population. The FPS data also had incomplete vehicle data with only 46% of data available for analysis. Lastly, for geocoded data, FPS data showed double counting and missing information that did not account for 48 fatalities. The iPAS geocoded data provided better information, however, gaps are present in this dataset as well.

5.3 Improvements to the Study

Firstly, the data available for this study could not be verified to ensure that data provided is correct. For instance, in the case of Central Cape Town, it is presumed that the absolute fatality number may have been affected by the mortuary location. The reason for this presumption is that, FPS data collectors designate the mortuary location to fatalities whose locations are unknown. Furthermore, the data contained missing information in the case of certain analysis (discussed in the previous section). In order to perform a comprehensive analysis, authorities concerned need to improve the following for the existing data:

- Improve data capturing on the fatality sites. This includes training data capturers on the fatality information required at each site and educating the data collectors on the importance of correct information.
- Ensure that SAPS and other authorities record fatalities in both urban and rural areas.
- Improve the capturing of geocoded data. This point can be encompassed in the first recommendation but a separate recommendation is made for this data since, the interventions introduced can change significantly, based on geocoded data. This dataset provided information on where fatalities occur and authorities can use this information to perform infrastructure audits in order to determine the appropriate measure.

Secondly, time restrictions and requirements of the minor dissertation limited the scope of the analysis performed. Additional analysis would have included an emergency care facility analysis (similar to one performed by Vanderschuren and McKune, 2015) that determined the post-accident interventions for the hazardous zones in the City.

Lastly, the scope of this dissertation also limited the investigations performed for the hazardous zones. These investigations were limited to analysing the data to determine the cause of the fatalities and presuming the interventions based on Google Earth images. An ideal method would include performing site investigations where a survey of the area would suggest the localised problem.

5.4 Further Applications of the Study

The methodology adopted in this study and findings of the study can be used in future research to:

- Perform a similar analysis in other municipalities and cities in LMIC, where the fatality burden is high, if access to data is available.
- Determine the areas in the city that require prioritisation in terms of road safety interventions.
- Further investigate the analysis districts that have high fatalities per annum and high fatality rates per 100 000 population, in order to reduce the burden of road fatalities.

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7. APPENDIX

Chapter 3: Methodology

List of modes

Train, Long distance train, Bus, BRT bus, Metered taxi, Minibus Taxi, Long-distance minibus taxi, Sedan taxi, Bakkie taxi, Car passenger, Car driver, Truck passenger, Truck driver, Company vehicle, Motorcycle, Bicycle, Animal-drawn transport, Boat, Aircraft, Gautrain, Walk and Other.

Data for figures used:

Figure 3-5

TAZ Number	District Name	Population
9020	Atlantis	335250
9021	Kraaifontein	219566
9023	Bellville	288856
9025	Blue Downs	515551
9025	Belgravia	195859
9026	Grassy Park	281853
9027	Mitchells Plain	521307
9028	Khayelitsha	393285
9029	Somerset West	35607
9030	Central Cape Town	128859
9031	Kuilsrivier	98950
9032	Durbanville	53103
9033	Oostenberg	152751
9035	Langa	255916
9036	Strand	196135
9037	Simonstown	110751
9038	Wynberg	152957
9039	Gugulethu	165595
9050	Sea Point	115331

Figure 3-5

Sex	Population
Male	2009527
Female	2093795

Figure 3-6

Age Group	Population
0-6	577578
7-15	510529
15-19	309955
20-25	502581
26-50	976717
51-65	868270
>=65	197715
blank (not considered)	360088

Chapter 4: Findings

Data for figures used:

Figure 4-1

	2011	2012	2013	2015	2015
Cyclists	100	53	60	60	107
Driver	100	131	123	117	173
Motorcycle	100	170	155	130	127
Passengers	100	115	100	86	95
Pedestrians	100	107	105	108	111
Total	**100**	**115**	**107**	**105**	**118**

Figure 4-2

	Cyclists	Driver	Motorcycle	Passengers	Pedestrians
Cape Town	59	568	224	543	1940
Western Cape	157	1322	330	1573	2935

Figure 4-3 and 4-4

District	Cyclist	Driver	Motorcycle	Passengers	Pedestrians	Total
Atlantis	8	52	19	36	55	**169**
Kraaifontein	2	38	21	51	119	**222**
Bellville	6	67	30	70	169	**355**
Blue Downs	8	58	13	57	255	**381**
Belgravia	1	18	6	10	75	**110**
Grassy Park	2	29	11	20	153	**215**
Mitchells Plain	5	50	7	32	228	**311**
Khayelitsha	1	57	5	65	256	**373**
Somerset West	0	11	5	16	19	**50**
Central Cape Town	1	62	36	59	167	**327**
Kuilsrivier	1	5	6	10	26	**58**
Durbanville	3	36	22	20	106	**187**
Oostenberg	0	0	0	0	0	**0**
Langa	0	9	1	10	37	**57**
Strand	1	5	6	8	50	**59**
Simonstown	13	23	17	27	56	**126**
Wynberg	2	28	12	28	37	**109**
Gugulethu	0	12	0	21	117	**150**
Sea Point	5	8	7	3	15	**36**

Figure 4-5

District	Train	Bus	Metered Taxi	Minibus Taxi	Car Passenger	Car	Cycle	Walk	Other
Atlantis	0,5%	13,4%	0,0%	17,7%	15,7%	25,4%	0,6%	21,9%	4,8%
Kraaifontein	15,5%	0,8%	0,0%	12,2%	12,7%	24,2%	0,6%	31,4%	2,6%
Bellville	9,0%	1,5%	0,0%	15,3%	17,7%	25,5%	0,2%	27,3%	3,4%
Blue Downs	13,3%	3,3%	0,4%	20,6%	8,5%	5,0%	0,6%	43,7%	4,6%
Belgravia	5,3%	4,4%	0,0%	16,6%	25,7%	19,5%	0,5%	24,9%	3,0%
Grassy Park	12,8%	4,4%	0,0%	17,6%	18,1%	20,5%	0,3%	23,8%	2,6%
Mitchells Plain	14,4%	9,3%	0,0%	22,7%	5,7%	4,6%	0,2%	41,2%	1,9%
Khayelitsha	23,5%	12,3%	0,0%	19,3%	4,1%	2,6%	0,0%	36,1%	2,2%
Somerset West	0,0%	0,0%	0,0%	0,0%	22,5%	77,5%	0,0%	0,0%	0,0%
Central Cape Town	14,6%	2,5%	0,2%	13,3%	23,5%	20,6%	0,2%	21,8%	3,3%
Kuilsrivier	9,6%	1,6%	0,3%	9,1%	19,2%	33,0%	0,2%	25,7%	1,3%
Durbanville	1,2%	0,7%	0,0%	0,3%	28,0%	51,7%	0,5%	10,3%	7,1%
Oostenberg	4,1%	0,8%	0,0%	1,6%	33,8%	52,9%	0,0%	4,2%	2,6%
Langa	8,4%	5,1%	0,2%	20,0%	16,8%	8,6%	0,3%	37,6%	3,0%
Strand	4,6%	0,5%	0,4%	15,8%	18,0%	30,3%	0,0%	24,4%	6,0%
Simonstown	7,0%	0,6%	0,0%	11,7%	26,1%	36,9%	0,3%	12,1%	5,3%
Wynberg	6,9%	0,5%	0,0%	4,1%	23,5%	51,4%	0,5%	10,6%	2,6%
Gugulethu	14,4%	9,3%	0,0%	22,7%	5,7%	4,6%	0,2%	41,2%	1,9%
Sea Point	2,1%	2,2%	2,5%	11,5%	16,9%	47,4%	0,0%	14,9%	2,6%

Figure 4-6

Cyclist

District	Percentage Mode Share	Percentage Fatalities	Difference
Atlantis	0,8	5,3	4,6
Kraaifontein	0,8	1,0	0,2
Bellville	0,2	1,9	1,7
Blue Downs	0,7	2,2	1,5
Belgravia	0,6	1,0	0,4
Grassy Park	0,3	1,0	0,7
Mitchells Plain	0,3	1,3	1,0
Khayelitsha	0,0	0,3	0,3
Somerset West	0,0	0,0	0,0
Central Cape Town	0,3	0,3	0,1
Kuilsrivier	0,2	2,4	2,2
Durbanville	0,5	1,8	1,3
Oostenberg	0,0	0,0	0,0
Langa	0,3	0,0	-0,3
Strand	0,0	1,9	1,9
Simonstown	0,3	11,9	11,6
Wynberg	0,5	2,1	1,6
Gugulethu	0,3	0,0	-0,3
Sea Point	0,0	13,8	13,8

Pedestrian

District	Percentage Mode Share	Percentage Fatalities	Difference
Atlantis	25,4	36,0	10,6
Kraaifontein	37,5	59,5	22,0
Bellville	30,6	54,2	23,6
Blue Downs	52,4	66,6	14,2
Belgravia	27,6	71,8	44,2
Grassy Park	28,7	75,0	46,3
Mitchells Plain	54,0	75,0	21,0
Khayelitsha	56,2	69,6	13,4
Somerset West	0,0	41,3	41,3
Central Cape Town	26,2	57,8	31,5
Kuilsrivier	28,9	61,9	33,0
Durbanville	10,5	64,2	53,7
Oostenberg	4,4	0,0	-4,4
Langa	43,5	66,1	22,6
Strand	25,7	75,5	49,8
Simonstown	13,1	42,2	29,1
Wynberg	11,4	38,9	27,6
Gugulethu	54,0	75,9	21,9
Sea Point	15,5	48,3	32,8

Driver

District	Percentage Mode Share	Percentage Fatalities	Difference
Atlantis	28,0	34,7	6,7
Kraaifontein	30,1	19,0	-11,1
Bellville	29,8	21,5	-8,3
Blue Downs	8,5	15,8	7,2
Belgravia	22,6	17,5	-5,1
Grassy Park	25,7	14,2	-11,5
Mitchells Plain	10,2	13,2	3,0
Khayelitsha	6,7	12,8	6,1
Somerset West	77,5	23,9	-53,6
Central Cape Town	26,0	21,5	-4,6
Kuilsrivier	37,8	11,9	-25,9
Durbanville	52,5	21,8	-30,6
Oostenberg	55,4	0,0	-55,4
Langa	11,9	16,1	4,2
Strand	33,7	7,5	-26,1
Simonstown	41,0	21,1	-19,9
Wynberg	55,7	29,5	-26,2
Gugulethu	10,2	8,6	-1,5
Sea Point	51,0	27,6	-23,4

Passenger

District	Percentage Mode Share	Percentage Fatalities	Difference
Atlantis	44,5	24,0	-20,5
Kraaifontein	28,9	20,5	-8,4
Bellville	36,1	22,4	-13,7
Blue Downs	35,0	15,5	-19,5
Belgravia	47,3	9,7	-37,6
Grassy Park	43,8	9,8	-34,0
Mitchells Plain	39,3	10,5	-28,7
Khayelitsha	43,3	17,4	-25,9
Somerset West	22,5	34,8	12,3
Central Cape Town	44,4	20,4	-24,0
Kuilsrivier	32,2	23,8	-8,4
Durbanville	29,4	12,1	-17,2
Oostenberg	37,5	0,0	-37,5
Langa	43,4	17,9	-25,6
Strand	34,4	15,1	-19,4
Simonstown	40,0	24,8	-15,2
Wynberg	29,7	29,5	-0,2
Gugulethu	39,3	15,5	-23,7
Sea Point	31,2	10,3	-20,8

Figure 4-7, Figure 4-9 and Figure 4-11

District	Total	Population	Average Annual Fatalities	Average Annual Fatalities/100 000 Population
Atlantis	169	335250	33,8	10,1
Kraaifontein	222	219566	55,5	20,2
Bellville	355	288856	68,8	23,8
Blue Downs	381	515551	76,2	18,3
Belgravia	110	195859	22	11,3
Grassy Park	215	281853	53	15,3
Mitchells Plain	311	521307	62,2	11,9
Khayelitsha	373	393285	75,6	19,0
Somerset West	50	35607	10	28,9
Central Cape Town	327	128859	65,5	50,8
Kuilsrivier	58	98950	9,6	9,7
Durbanville	187	53103	37,5	70,5
Langa	57	255916	11,5	7,5
Strand	59	196135	11,8	5,6
Simonstown	126	110751	25,2	12,8
Wynberg	109	152957	21,8	19,7
Gugulethu	150	165595	30	18,13
Sea Point	36	115331	7,2	5,5

Figure 4-8

District	Cyclist	Driver	Motorcycle	Passengers	Pedestrians	Total
Atlantis	1,6	10,5	3,8	7,2	10,8	33,8
Kraaifontein	0,5	7,6	5,2	8,2	23,8	55,5
Bellville	1,2	13,5	6,0	15,0	33,8	68,8
Blue Downs	1,6	11,6	2,6	11,5	59,0	76,2
Belgravia	0,2	3,6	1,2	2,0	15,8	22,0
Grassy Park	0,5	5,8	2,2	5,0	30,6	53,0
Mitchells Plain	0,8	8,0	1,5	6,5	55,6	62,2
Khayelitsha	0,2	9,5	0,8	12,8	51,2	75,6
Somerset West	0,0	2,2	0,8	3,2	3,8	10,0
Central Cape Town	0,2	12,5	7,2	11,8	33,5	65,5
Kuilsrivier	0,2	1,0	1,2	2,0	5,2	9,6
Durbanville	0,6	7,2	5,5	5,0	21,2	37,5
Langa	0,0	1,8	0,2	2,0	7,5	11,5
Strand	0,2	0,8	1,2	1,6	8,0	11,8
Simonstown	2,6	5,6	3,5	5,5	9,2	25,2
Wynberg	0,5	5,6	2,5	5,6	7,5	21,8
Gugulethu	0,0	2.5	0,0	5,2	23,8	30.0
Sea Point	0,8	1,6	1,5	0,6	2,8	7,2
Total	**11,5**	**109,5**	**55,5**	**106,5**	**381,5**	**655,8**

Figure 4-10

District	Cyclist	Driver	Motorcycle	Passengers	Pedestrians
Atlantis	0,58	3,11	1,15	2,15	3,23
Kraaifontein	0,18	3,56	1,91	3,73	10,85
Bellville	0,52	5,65	2,08	5,85	11,70
Blue Downs	0,39	2,79	0,63	2,75	11,79
Belgravia	0,10	1,85	0,62	1,03	7,60
Grassy Park	0,15	2,06	0,78	1,52	10,86
Mitchells Plain	0,15	1,53	0,27	1,23	8,75
Khayelitsha	0,05	2,39	0,20	3,25	13,02
Somerset West	0,00	6,36	2,31	9,25	10,98
Central Cape Town	0,16	9,62	5,59	9,16	25,92
Kuilsrivier	0,20	1,01	1,21	2,02	5,26
Durbanville	1,13	13,56	8,29	7,53	39,92
Oostenberg	0,00	0,00	0,00	0,00	0,00
Langa	0,00	0,71	0,08	0,78	2,90
Strand	0,10	0,51	0,61	0,82	5,08
Simonstown	2,35	5,15	3,07	5,88	8,31
Wynberg	0,28	3,92	1,68	3,92	5,18
Gugulethu	0,00	1,55	0,00	2,55	15,15
Sea Point	0,69	1,39	1,21	0,52	2,53

Figure 4-13

District	Blank	Unknown	Other
Atlantis	33%	1%	5%
Kraaifontein	37%	7%	5%
Bellville	57%	6%	1%
Blue Downs	51%	7%	1%
Belgravia	41%	4%	2%
Grassy Park	35%	8%	0%
Mitchells Plain	38%	7%	1%
Khayelitsha	50%	10%	2%
Somerset West	34%	8%	0%
Central Cape Town	55%	3%	2%
Kuilsrivier	46%	10%	0%
Durbanville	40%	8%	2%
Langa	42%	11%	0%
Strand	36%	16%	0%
Simonstown	38%	4%	2%
Wynberg	55%	1%	1%
Gugulethu	40%	3%	0%
Sea Point	61%	3%	3%

Google Earth images of other hazardous zones:


Cape Town iPAS
Legend
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M11
Caledon St
Google Earth
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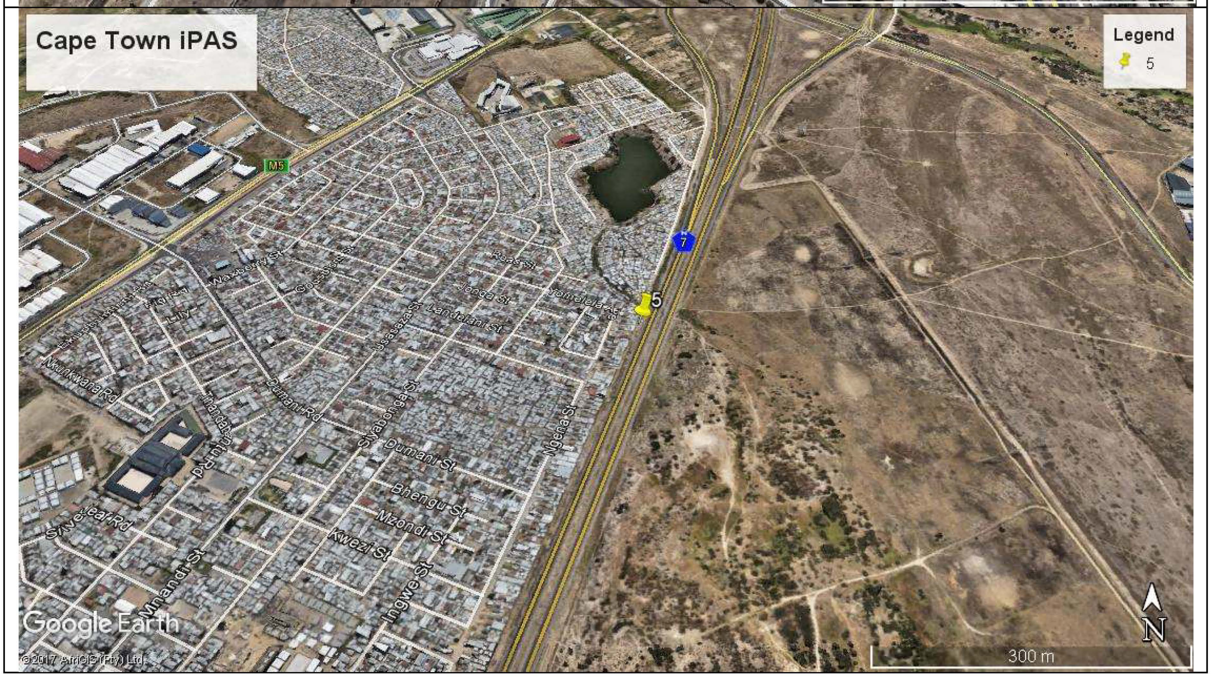
Cape Town iPAS
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Cape Town iPAS
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Paarden Eiland Rd
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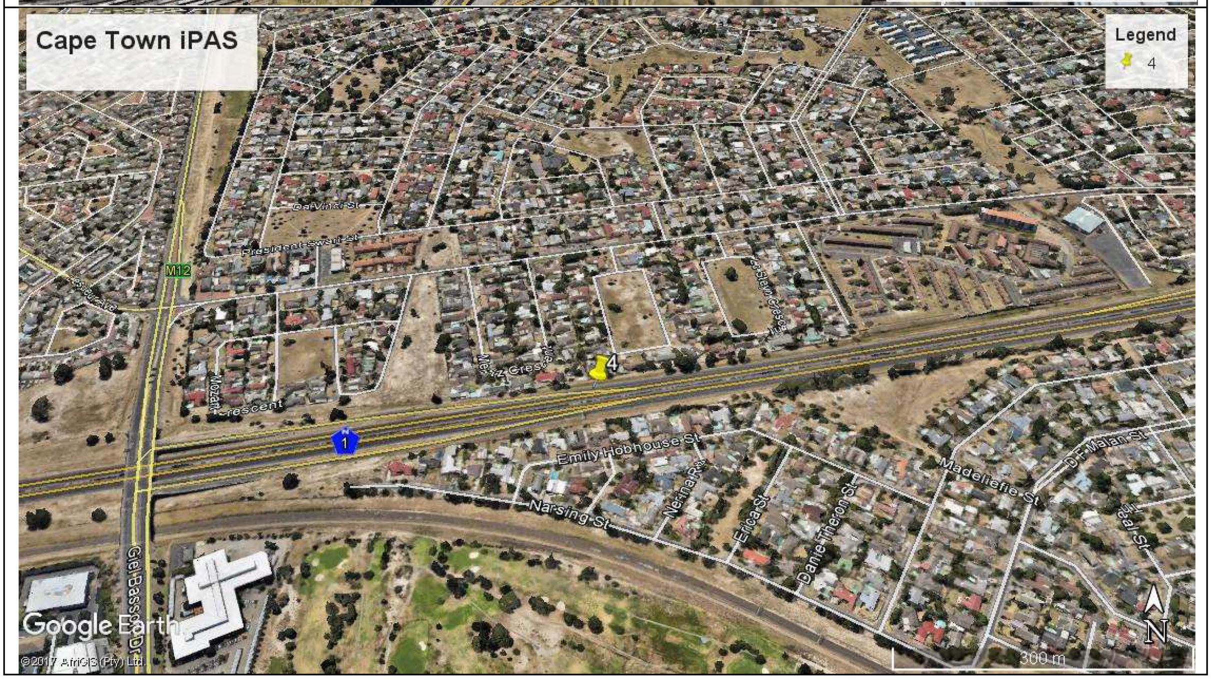
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Cape Town iPAS
Legend
3
M18
2
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Kliptontein Rd
Nhlangano Crescent
Settlers Weg
Mzamka St
Miller St
Falcon Cres
Google Earth
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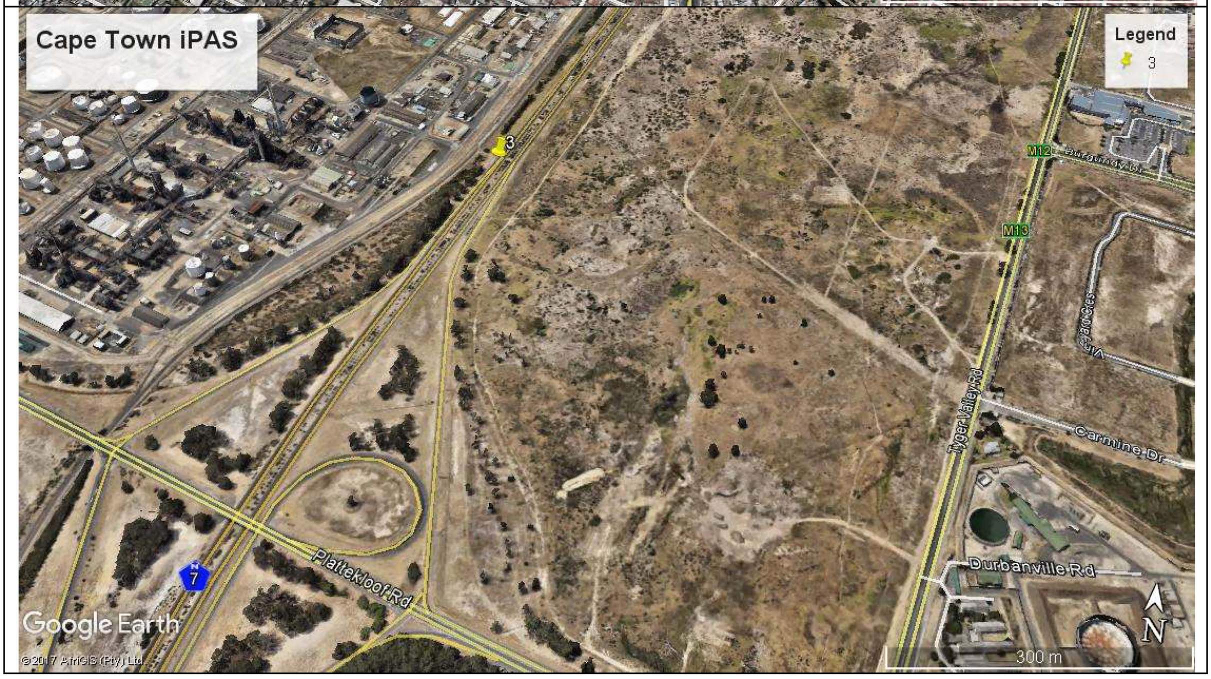
Cape Town iPAS
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Plattekloof Rd
7
Google Earth
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